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USE OF FOAM TO REDUCE GUN BLAST NOISE LEVELS.(U) F/G 19/6
MAR 81 L L PATER, J W SHEA
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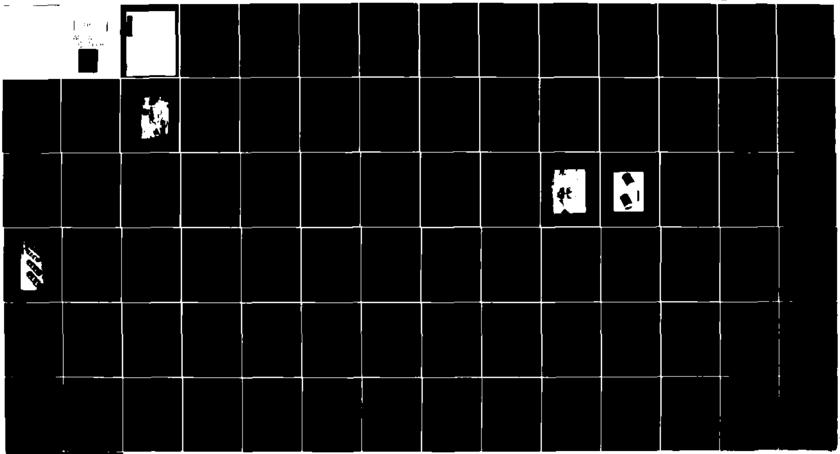

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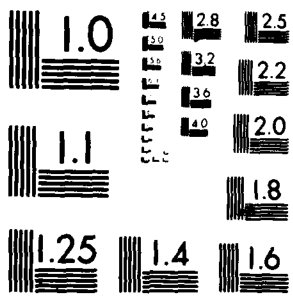

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It was conclusively demonstrated that aqueous foam can effect significant (greater than 10 dB) reductions in gun muzzle blast peak sound pressure level; reductions of more than 10 dB were attained. In addition, muzzle flash was eliminated completely. Containment of the foam in a muzzle-mounted canister appears to offer a feasible and operationally acceptable method of exploiting the phenomenon.

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FOREWORD

This report was prepared as part of a development program to determine methods of reducing noise levels due to Naval weapons, particularly large guns, during training and testing operations. Early work was funded by the Naval Science Assistance Program (NSAP) at the request of COMTHIRDFLT and by the Navy Independent Research program The majority of work was carried out under the Gun Blast Effects program, NAVSEATASK 653/497/004-1-S0956.

This report has been reviewed and approved by F. H. Maillie and J. F. Horton of the Systems Safety Division of the Combat Systems Department.

Released by:

THOMAS A. CLARE, Head
Combat Systems Department

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INTRODUCTION

OBJECTIVE

The objective of the experiments reported herein was to determine the effectiveness of foam for reducing gun muzzle blast noise.

BACKGROUND

The current study was part of a larger exploratory investigation[1,2] undertaken to identify techniques or devices that could significantly reduce public noise disturbance resulting from the firing of large guns at Naval testing and training ranges. Such a technique or device would ideally be suitable for temporary use with existing gun systems, without requiring significant modification of or causing damage to the gun system or platform. Training and testing requirements dictate that only a negligible effect on bullet trajectory could be tolerated, and impact on training/testing operations should be as minimal as possible.

There are three sources of noise associated with firing a gun; these are the muzzle blast that occurs when the projectile uncorks the high pressure propellant gases, the bow shock (sonic boom) of the supersonic projectile, and projectile detonation. If the gun is actually to be fired, each of these noise sources will probably require separate noise reduction techniques. Projectile detonation noise can be eliminated or reduced by using projectiles that are inert or contain only a very small spotting charge. The projectile bow shock noise field is discussed in some detail in another report[1] and will be only discussed briefly here. Projectile bow shock exists in only a portion of the blast field, typically within a sector of about 60° to either side of the line of fire. Within this region, bow shock noise level at the earth's surface varies according to a complicated dependence upon projectile trajectory, projectile speed along the trajectory, projectile size and shape, and atmospheric acoustic refraction. The bow shock noise may be more significant than muzzle blast noise at some field locations, especially near the line of fire. Noise exposure due to projectile bow shock can be minimized by stopping the projectile at the shortest possible range, or by controlling the direction of fire so as to avoid noise sensitive regions. It should be noted that a muzzle blast noise reduction technique that has no effect on the projectile velocity or trajectory will have no effect on the projectile bow shock noise field.

One concept for reducing muzzle blast noise level is to introduce some substance into the muzzle region to interact with and remove energy from the blast wave. Recent experiments[3,4] with bare explosive charges have shown that foam can yield large reductions in airblast noise level. In these experiments, the explosive charge was engulfed in aqueous foam such as that used in fire-fighting.

A cursory preliminary investigation[2] into the utility of foam for reducing gun muzzle blast noise was quite encouraging. A small (diameter ~ 20 calibers) plastic bag full of shaving cream attached to a rifle muzzle yielded about 10 dB reduction in far field peak sound pressure level (PSPL). This motivated the more extensive investigation documented in this report.

BASELINE: BARE MUZZLE

The near field peak overpressure distribution for bare muzzle guns has been extensively documented.[5-10] Figure 1 shows a typical near field peak overpressure distribution.[6,*] Figure 2 shows the same blast field expressed as PSPL,** and Figure 3 explicitly shows the peak sound pressure level directivity

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* This blast field is an average for a wide variety of Naval guns. Approximate similitude was achieved by expressing radial distance from the gun muzzle in units of calibers, one caliber being equal to the gun bore diameter.

** Peak sound pressure level (PSPL, or L_{Pk}) is a logarithmic comparison scale defined by

$$L_{Pk} = 10 \log_{10}\left(\frac{P_M}{P_0}\right)^2 = 20 \log_{10} \frac{P_M}{P_0}$$

in units of decibels, where P_M = peak overpressure and $P_0 = 20\ \mu P_a = 2.9 \times 10^{-9}$ psi = reference overpressure for 0 dB.

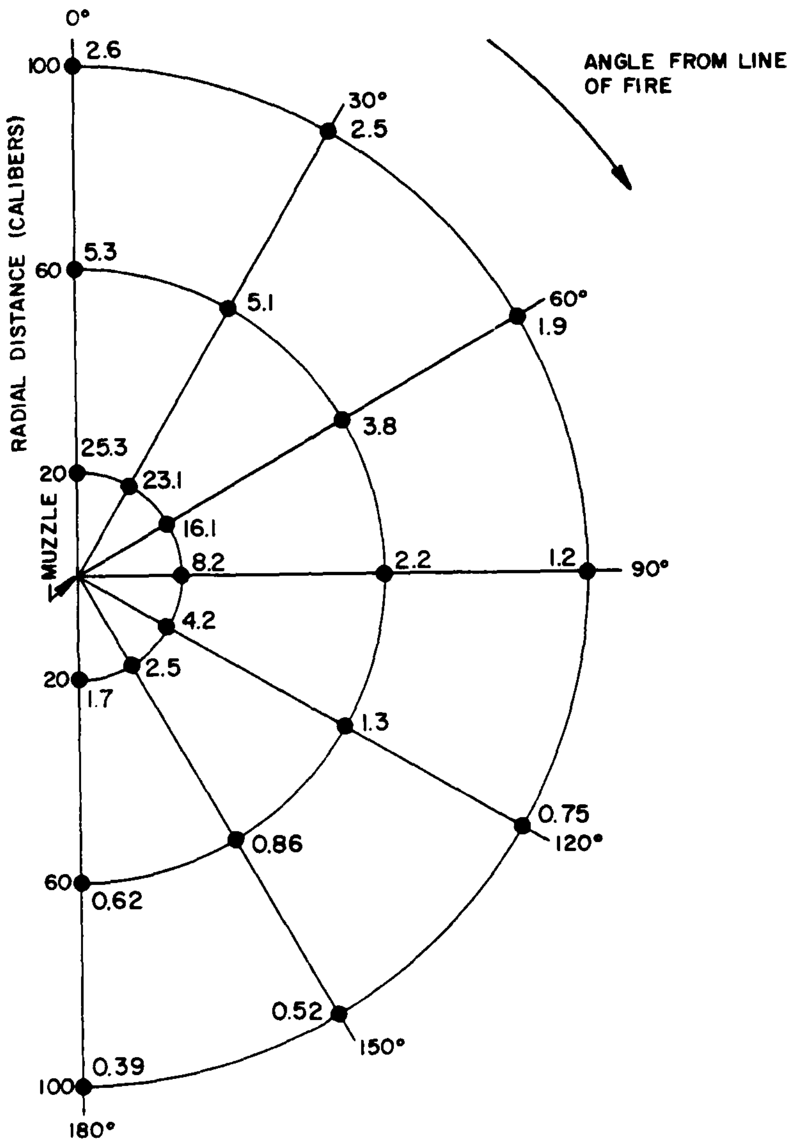

Figure 1. Bare Muzzle Near Field Peak Overpressure (psi)

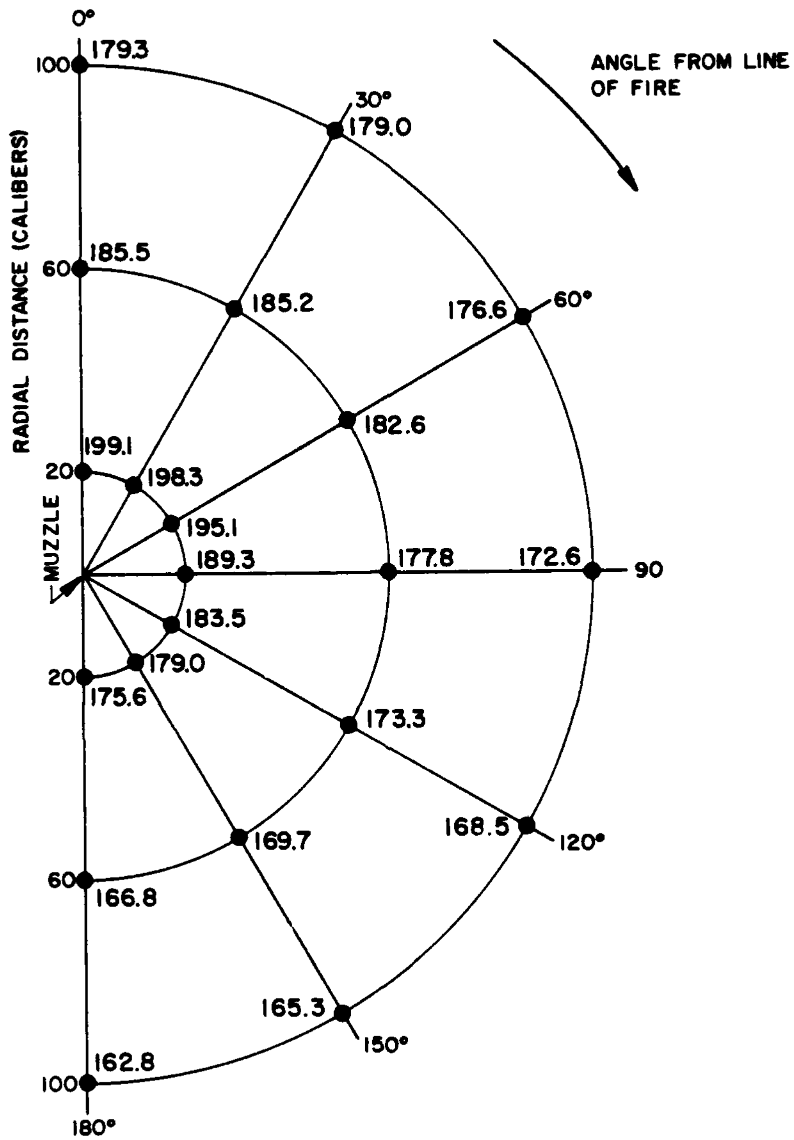

Figure 2. Bare Muzzle Near Field Peak Sound Pressure Level (dB)

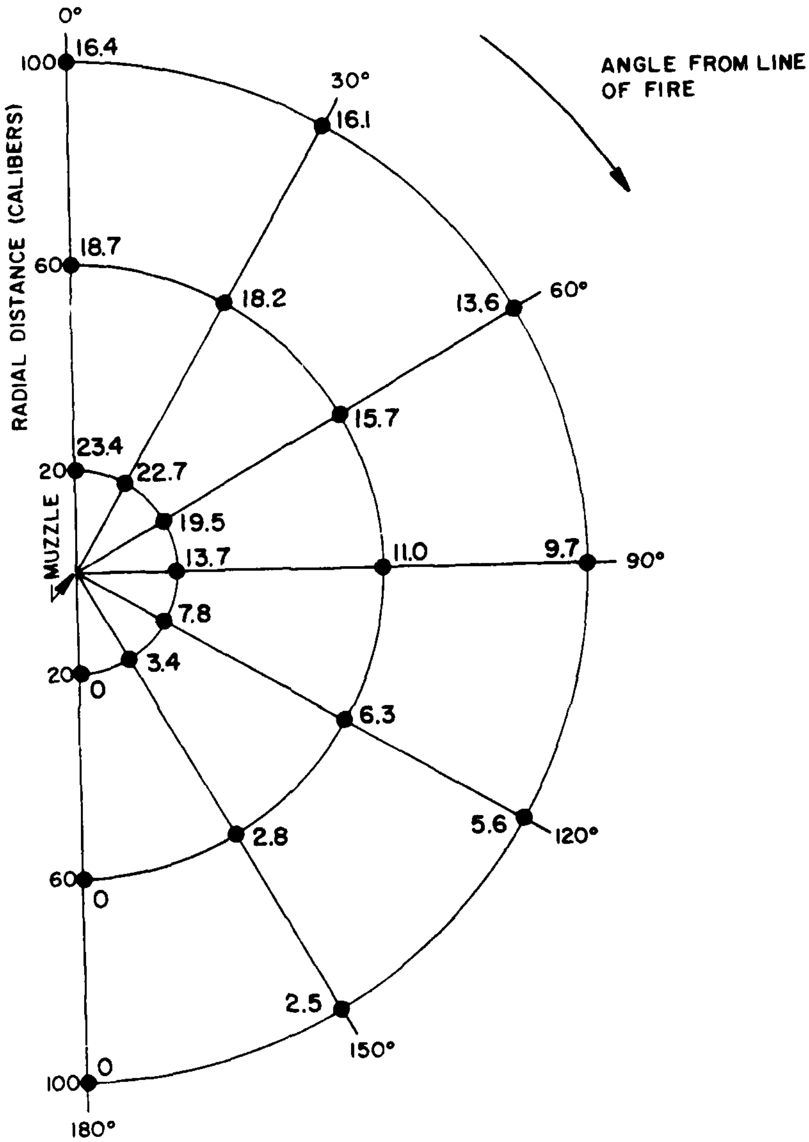

Figure 3. Bare Muzzle Near Field Directivity (dB) re 180°

relative to 180° from the line of fire. This same near field directivity information is shown in different format in Figure 4. Also shown in Figure 4 is near field data for the .308 (7.62 mm) rifle used to obtain most of the data presented in this report. It can be seen that the .308 rifle near field peak directivity agrees quite well with that of large Naval guns. The general validity of reduced scale investigation of near field gun muzzle blast has been well established.[1,5,6,7,11]

Recent work[1,12] has shown that gun muzzle blast PSPL directivity amounts to about 14 to 17 dB, and is essentially constant for a given gun, throughout the far field.* The far field PSPL directivity[1] of the .308 rifle used in the present investigation is shown in Figure 4. It has also been shown[1] that the .308 rifle is an adequate scale replica of large guns for purposes of reduced scale blast field investigation.

PROCEDURES AND APPARATUS

The noise parameter that was measured throughout the current study was peak unweighted sound pressure level. The results of the various noise reduction experiments are presented in terms of reduction of far field PSPL from the far field directivity curve** shown in Figure 4. This data presentation is meaningful since both far field directivity and the noise reduction due to foam are practically invariant throughout the far field, except for variations and distortions caused by atmospheric refraction.

The noise reduction effect of foam was measured directly by using two closely juxtaposed guns, one bare muzzle and one employing the noise reduction technique. The guns were fired consecutively within about 10 to 12 seconds. The

* Data have been presented for distances in excess of 100,000 calibers.

** These results may be translated into absolute levels through the use of available models[1,12] for bare muzzle far field gun blast, expressed as a function of distance from the gun, the angle from the direction of fire, and the gun elevation angle, for various atmospheric propagation conditions.

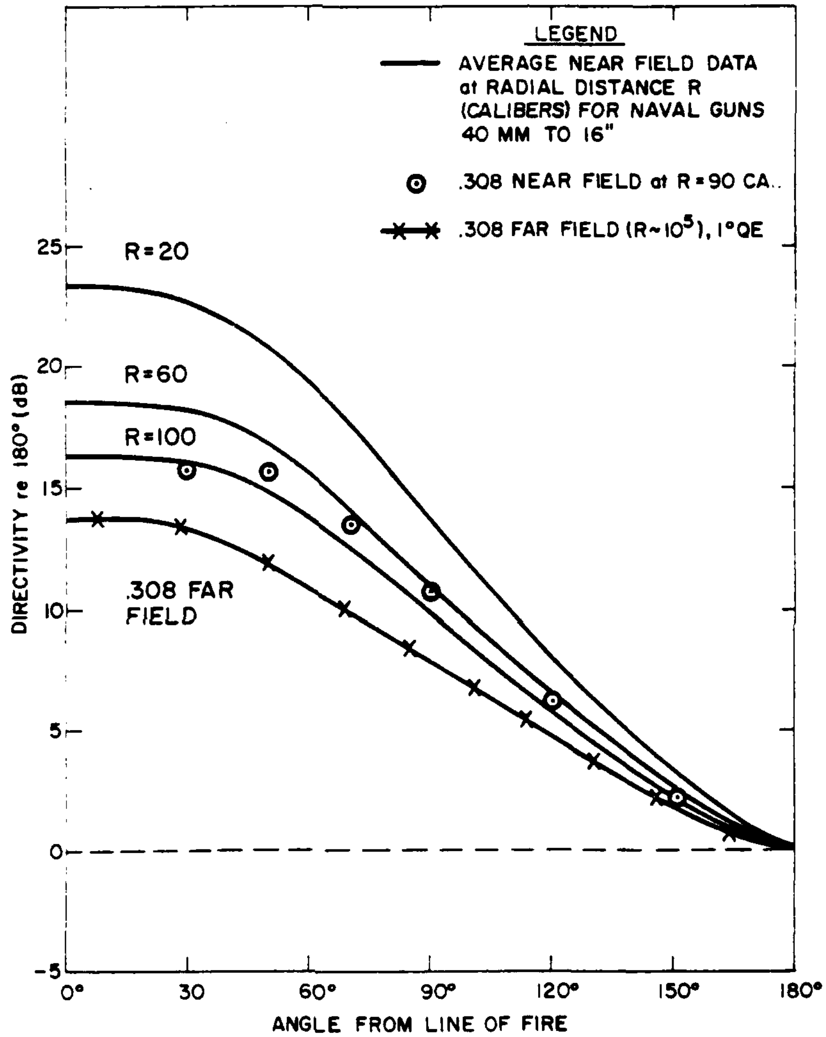

Figure 4. Muzzle Blast Directivity

parameter of interest was the difference in noise level for the two guns (i.e., the amount of noise reduction).

The above procedure was intended to minimize data scatter based on the assumption that atmospheric propagation conditions do not vary greatly during a short time interval. Wind gusts or atmospheric turbulence can nevertheless result in significant data scatter. Nearly all testing was conducted at night to take advantage of relatively stable atmospheric propagation conditions and minimal winds. Data scatter was further minimized by using ammunition from a single specially-selected production lot.

The guns used to obtain the data were 7.62 mm NATO (.308) rifles, Remington Model 788 bolt action, unmodified except for machining of external threads on the muzzle. Two guns were mounted on a machine-gun tripod in an over-and-under configuration by means of custom brackets as shown in Figure 5. Projectile bow shock was eliminated from the blast field by means of bullet traps located a few hundred calibers downrange from the gun muzzle. A small piece of tape was placed over the muzzle, as a safety precaution, to exclude foam from the gun bore.

Data acquisition was by means of modified Gen Rad Model 1982 sound level meters. For measurement of PSPL, the meter control settings used were the "flat" weighting, the "peak" detector, the octave filter selector set to "WTG" (broad band), and the range switch set to the appropriate dB range. Ten dB attenuators were used when the PSPL exceeded 140 dB. The meters were modified to make the PSPL value available as a constant voltage at the "DC out" jack, output linear in dB. This voltage was transmitted, via land lines, using a specially-fabricated "line driver" from each instrumentation location to an instrumentation van where the voltage values were sequentially and rapidly recorded by means of a Datel Systems Model PDL-10 Data Logger. The recorded voltages were converted to dB values during data reduction by means of voltage vs dB calibration curves previously prepared for each sound level meter. The meters were also modified by installation of a small solenoid used to remotely actuate (from the instrumentation van) reset of the peak and hold circuitry. Sound level meters were

Figure 5. .308 Gun Mount

calibrated before each test by means of Gen Rad Model 1567 1000 Hz Sound Level Calibrators. Wind conditions were monitored by means of an anemometer located at the gun site.

PRELIMINARY TESTING

Results of the first attempt to use foam to reduce gun muzzle blast noise, reported in detail in another report,[2] are included here as Table 1. This test used shaving cream foam contained in a plastic bag taped to the muzzle of a 7.62 mm rifle. The foam mass was roughly spherical, about 20 calibers in diameter, with the gun muzzle located approximately at the center. PSPL values were measured at four far field distances as shown in Table 1, at 90° from the direction of fire. The data exhibit considerable scatter but show quite conclusively that neither the empty plastic bag nor the tape over the muzzle (to exclude foam from the gun bore) had a significant* effect on far field PSPL. The effect of the foam was to reduce the PSPL by about 9 or 10 dB. The reduction appears to be independent of distance, except for refraction effects, as expected from theoretical considerations and from previous experience with other blast reduction techniques.

Similar but more extensive experiments were carried out to verify and extend the above results, particularly to determine PSPL reduction at angles other than 90° from the line of fire. A total of six sound level meters was used, located at 45°, 90° and 135° to either side of the direction of fire, all at a distance of 4,000 calibers. A variety of foams and foam containers was tested. Results are listed in detail in Tables 2 through 6.

* It is generally agreed that, for occasional noise events, unaided human hearing cannot reliably detect differences in PSPL smaller than about 3 dB. On the other hand, a change of 10 dB seems to correspond roughly to a factor of two change in subjective noisiness or annoyance. Thus, any noise reduction technique that yields a change in noise level of less than 3 dB is of little or no value in terms of reducing human annoyance. It should also be recognized that the PSPL alone is not necessarily an adequate descriptor of human annoyance since other parameters such as duration and spectral energy distribution can be of importance. PSPL offers the advantage of being easy to measure with available field instruments.

Table 1. 7.62 mm Gun Initial Foam Experiment

Round Number	Remarks	PSPL (dB) @ 90° from Line of Fire, R (calibers) =				Mean Δ PSPL (dB)
		14,000	26,000	80,200	138,000	
1	Tape over muzzle	117.9	109.6	95.6	88.7	
2	BM (Bare Muzzle)	117.8	105.1	97.2	95.2	
1-2	Δ PSPL	+0.1	+4.5	-1.6	-6.5	-0.9
3	Tape	117.7	111.3	96.8	90.8	
4	BM	117.8	105.6	100.8	93.9	
3-4	Δ PSPL	-0.1	+5.7	-4.0	-3.1	-0.4
5	Tape	117.4	108.7	100.3	89.4	
6	BM	116.1	108.6	97.2	97.5	
5-6	Δ PSPL	+1.3	+0.1	+3.1	-8.1	-0.9
7	Tape	117.9	110.5	103.6	96.4	
8	BM	117.3	110.1	99.8	91.9	
7-8	Δ PSPL	+0.6	+0.4	+3.8	+4.5	+2.3
9	Tape	117.4	110.6	100.7	91.4	
10	BM	118.0	112.1	100.5	100.6	
9-10	Δ PSPL	-0.6	-1.5	+0.2	-9.2	-2.8
1-10	Mean Δ PSPL (Effect of Tape)	+0.3	+1.8	+0.3	-4.5	-0.5

Table 1. 7.62 mm Gun Initial Foam Experiment (Cont'd)

Round Number	Remarks	PSPL (dB) @ 90° from Line of Fire, R (calibers) =				Mean Δ PSPL (dB)
		14,000	26,000	80,200	138,000	
11	Tape + Empty Bag	118.3	112.3	101.1	88.6	
12	BM	117.7	110.1	100.3	99.3	
11-12	Δ PSPL	+0.6	+2.2	+0.8	-10.7	-1.8
13	Tape + Empty Bag	116.8	109.4	103.7	98.0	
14	BM	118.9	111.4	103.2	98.3	
13-14	Δ PSPL	-2.1	-2.0	+0.5	-0.3	-1.0
15	Tape + Empty Bag	118.1	109.5	105.6	100.0	
16	BM	118.6	111.2	102.4	88.7	
15-16	Δ PSPL	-0.5	-1.7	+3.2	+11.3	+3.1
11-16	Mean Δ PSPL (Effect of Tape + Empty Bag)	-0.7	-0.5	+1.5	+0.1	+0.1
17	Foam*	107.2	101.4	84.9	89.2	
18	BM	118.6	111.9	97.4	98.0	
17-18	Δ PSPL	-11.4	-10 5	-12.5	-8.8	-10.8
19	Foam*	111.4	105.9	92.3	85.6	
20	BM	116.6	106.4	97.2	94.6	
19-20	Δ PSPL	-5.2	-0.5	-4.9	-9.0	-4.9

Table 1. 7.62 mm Gun Initial Foam Experiment (Cont'd)

Round Number	Remarks	PSPL (dB) @ 90° from Line of Fire, R (calibers) =				Mean Δ PSPL (dB)
		14,000	26,000	80,200	138,000	
21	Foam*	107.5	103.9	85.9	79.4	
22	BM	117.8	111.2	99.3	91.5	
21-22	Δ PSPL	-10.3	-7.3	-13.4	-12.1	-10.8
17-22	Mean Δ PSPL (Effect of foam)	-9.0	-6.1	-10.3	-10.0	-8.8

* Foam was contents of one 11-oz pressurized can of commercial shaving cream, expansion ratio ~ 10.

Table 2. Muzzle Blast Attenuation Experiments, Foam Configuration "A"

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
1	A*	136.0	122.0	115.7	119.1	118.5	126.4	
2	BM**	146.3	131.2	124.5	126.3	130.9	136.5	
1-2	Δ PSPL	-10.3	-9.2	-8.8	-7.2	-12.4	-10.1	-9.7
3	A	139.9	125.8	119.2	118.6	122.4	--	
4	BM	145.5	130.8	127.1	127.6	130.2	135.6	
3-4	Δ PSPL	-5.6	-5.0	-7.9	-9.0	-7.8	--	-7.1
5	A	138.2	123.4	115.5	120.2	120.4	128.2	
6	BM	145.2	131.1	126.0	126.8	131.3	134.7	
5-6	Δ PSPL	-7.0	-7.7	-10.5	-6.6	-10.9	-6.5	-8.2
7	A	136.8	123.8	117.6	120.4	120.5	126.1	
8	BM	141.3	133.4	125.2	126.5	128.7	135.8	
7-8	Δ PSPL	-4.5	-9.6	-7.6	-6.1	-8.2	-9.7	-7.6
9	A	135.8	125.5	120.1	122.4	122.3	126.3	
10	BM	146.3	131.3	127.8	129.6	130.5	135.1	
9-10	Δ PSPL	-10.5	-5.8	-7.7	-7.2	-8.2	-8.8	-8.0

Table 2. Muzzle Blast Attenuation Experiments, Foam Configuration "A" (Cont'd)

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
11	A	139.8	121.7	119.7	121.3	124.5	125.9	
12	BM	145.9	132.9	126.7	130.6	130.3	136.5	
11-12	Δ PSPL	-6.1	-11.2	-7.0	-9.3	-5.8	-10.6	-8.3
1-12	Mean Δ PSPL	-7.3	-8.1	-8.2	-7.6	-8.9	-9.1	-8.2

Test date: 1 February 1978

Wind ~ 5 kt variable from 135° left

* See text for description of configuration "A"

** BM = "Bare Muzzle"

Table 3. Muzzle Blast Attenuation Experiment, Foam Configuration "B"

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
1	B*	132.1	118.6	116.2	119.0	118.0	125.3	
2	BM**	148.3	130.9	124.0	126.3	131.1	135.3	
1-2	Δ PSPL	-16.2	-12.3	-7.8	-7.3	-13.1	-10.0	-11.1
3	B	135.6	122.7	119.1	118.4	119.1	124.9	
4	BM	146.0	131.4	126.3	126.6	129.7	134.4	
3-4	Δ PSPL	-10.4	-8.7	-7.2	-8.2	-10.6	-9.5	-9.1
5	B	132.2	116.0	116.3	115.7	115.2	119.0	
6	BM	144.7	133.3	125.3	129.4	131.8	135.0	
5-6	Δ PSPL	-12.5	-17.3	-9.0	-13.7	-16.6	-16.0	-14.2
7	B	139.2	126.3	119.3	115.2	116.4	119.9	
8	BM	148.3	138.2	130.6	126.5	131.5	133.4	
7-8	Δ PSPL	-9.1	-11.9	-11.3	-11.3	-15.1	-13.5	-12.0
1-8	Mean Δ PSPL	-12.0	-12.6	-8.8	-10.1	-13.8	-12.2	-11.6

Test date: 1 February 1978. Wind ~ 5 kt variable from 135° left.

* See text

**Bare Muzzle

Table 4. Muzzle Blast Attenuation Experiments, Foam Configuration "C"

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
1	C*	138.5	128.4	119.3	120.8	120.1	126.6	
2	BM**	150.2	132.9	127.6	127.2	130.7	135.7	
1-2	Δ PSPL	-11.7	-4.5	-8.3	-6.4	-10.6	-9.1	-8.4
3	C	137.6	120.7	115.5	117.8	118.7	122.7	
4	BM	144.9	133.2	127.1	127.5	132.1	135.1	
3-4	Δ PSPL	-7.3	-12.5	-11.6	-9.7	-13.4	-12.4	-11.2
5	C	134.9	122.1	117.0	118.8	121.1	122.9	
6	BM	146.9	132.5	124.5	127.9	130.9	134.6	
5-6	Δ PSPL	-12.0	-10.4	-7.5	-9.1	-9.8	-11.7	-10.1
7	C	136.3	121.8	115.2	118.9	118.0	125.7	
8	BM	146.8	132.5	124.4	129.0	132.6	136.2	
7-8	Δ PSPL	-10.5	-10.7	-9.2	-10.1	-14.6	-10.5	-10.9
1-8	Mean Δ PSPL	-10.4	-9.5	-9.2	-8.8	-12.1	-10.9	-10.2

Test date: 1 February 1978. Wind ~ 5 kt variable from 135° left.

*See text.

** Bare Muzzle

Table 5. Muzzle Blast Attenuation Experiments, Foam Configuration "D"

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
1	D*	--	120.0	119.2	123.1	119.6	127.5	
2	BM**	--	130.7	123.8	128.8	127.9	136.1	
1-2	Δ PSPL	--	-10.7	-4.6	-5.7	-8.3	-8.6	-7.6
3	D	--	121.1	115.2	121.8	122.4	--	
4	BM	--	133.7	130.5	128.5	130.5	--	
3-4	Δ PSPL	--	-12.6	-15.3	-6.7	-8.1	--	-10.7
5	D	--	120.3	115.5	122.6	123.4	--	
6	BM	--	131.1	128.4	129.2	128.1	--	
5-6	Δ PSPL	--	-10.8	-12.9	-6.6	-4.7	--	-8.8
7	D	--	122.8	117.2	119.1	120.8	--	
8	BM	--	131.5	126.1	127.0	128.8	--	
7-8	Δ PSPL	--	-8.7	-8.9	-7.9	-8.0	--	-8.4
9	D + antifreeze	--	122.0	115.2	119.9	120.1	125.3	
10	BM	--	130.9	124.7	128.4	128.8	134.9	
9-10	Δ PSPL	--	-8.9	-9.5	-8.5	-8.7	-9.6	-9.0

Table 5. Muzzle Blast Attenuation Experiments, Foam Configuration "D" (Cont'd)

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
11	D + antifreeze	--	123.1	117.3	123.5	121.6	126.0	
12	BM	--	131.6	124.8	128.8	129.8	135.5	
11-12	Δ PSPL	--	-8.5	-7.5	-5.3	-8.2	-9.5	-7.8
13	D + antifreeze	--	123.5	117.1	119.3	119.6	126.0	
14	BM	--	131.2	123.8	127.8	129.1	135.6	
13-14	Δ PSPL	--	-7.7	-6.7	-8.5	-9.5	-9.6	-8.4
1-14	Mean Δ PSPL	--	-9.7	-9.3	-7.0	-7.9	-9.3	-8.6

Test date: 8 February 1978

Wind ~ 2 kt variable

* See text

** Bare Muzzle

Table 6. Muzzle Blast Attenuation Experiments, Foam Configuration "E"

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
1	E*	--	109.4	106.9	108.6	111.2	117.6	
2	BM**	--	132.5	121.7	125.6	128.9	135.7	
1-2	Δ PSPL	--	-23.1	-14.8	-17.0	-17.7	-18.1	-18.1
3	E	--	115.2	111.6	108.3	111.8	115.8	
4	BM	--	132.3	123.2	127.6	129.0	135.9	
3-4	Δ PSPL	--	-17.1	-11.6	-19.3	-17.2	-20.9	-17.2
5	E	--	112.5	111.2	114.7	111.2	118.0	
6	BM	--	130.8	124.0	128.4	128.1	135.3	
5-6	Δ PSPL	--	-18.3	-12.8	-13.7	-16.9	-17.3	-15.8
7	E	--	113.8	108.1	109.6	109.2	116.2	
8	BM	--	131.6	123.0	127.4	128.9	134.9	
7-8	Δ PSPL	--	-17.8	-14.9	-17.8	-19.7	-18.7	-17.8
9	E	--	112.1	110.3	114.5	112.4	116.6	
10	BM	--	131.6	125.2	128.4	129.1	136.2	
9-10	Δ PSPL	--	-19.5	-14.9	-13.9	-16.7	-19.6	-16.9
1-10	Mean Δ PSPL	--	-19.2	-13.8	-16.3	-17.6	-18.9	-17.2

Test date: 8 February 1978. Wind ~ 1 kt variable.

* See text

** Bare Muzzle

Table 2 shows results for configuration "A", which was the foam contents of one 11-oz pressurized can of commercial shaving cream, E.R.* ~ 10. The foam was contained in a 2-mil thick, 1 gallon size plastic bag taped to the gun muzzle. The gun muzzle was located at about the center of the foam mass. The foam mass was roughly spherical with a diameter somewhat less than 20 calibers (probably about 16 calibers) and was not closely controlled in these preliminary exploratory experiments. The average effect was about an 8 dB reduction in PSPL. There did not appear to be any consistent or systematic variation in PSPL reduction as a function of the angle from the direction of fire. There was considerable, seemingly random, variation in PSPL reduction, which was probably the actual result of variations in the shape of the foam mass and the location of the muzzle within the foam, plus effects of changes in atmospheric propagation properties.

Configuration "B" was quite similar except that twice as much (two cans) shaving cream foam was used, contained in a 1-mil thick grocery produce bag. Diameter of the foam mass was about 20 calibers. Results are shown in Table 3. The average reduction in PSPL was over 11 dB. Larger reductions were generally obtained in front of the gun rather than behind the gun, but detailed conclusions are not warranted because neither the shape of the foam mass nor the location of the gun muzzle within the foam was closely controlled.

Configuration "C" was also quite similar except that about 1 gallon of aqueous foam, contained in a 1-mil thick grocery produce bag, was used. The foam was produced from a mixture of firefighting foam concentrate and water, mechanically agitated** to yield an E.R. $\approx$ 10. The diameter of the foam mass was about

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* E.R. = Expansion Ratio, a measure of foam density, defined as the ratio of the expanded foam to the volume of the original liquid constituents.

** An "egg beater" type of device, powered by a 2000 RPM electric drill, was used to produce the foam from the water/concentrate mixture.

25 calibers. Results, shown in Table 4, were very similar to those for the shaving cream foam configurations A & B; mean PSPL reduction was 10.2 dB.

Configuration "D" was identical to "C" except that a less dense foam was used. A similar mixture of firefighting foam concentrate and water was mechanically agitated to yield an E.R. of $\simeq$ 20. For some rounds, ethylene glycol base antifreeze was added to prevent freezing of the foam. Results, presented in Table 5, are again quite similar to those discussed above. Mean PSPL reduction was 8.6 dB. The presence of the antifreeze resulted in an insignificant* effect on PSPL reduction (Δ PSPL = -8.4 dB with antifreeze, -8.8 dB without antifreeze).

Configuration "E" was designed to determine the effect of an increased amount of foam. The foam used was similar to that used in Configuration "C", E.R. of $\simeq$ 10, but with antifreeze added to combat freezing. Four gallons of this foam were contained in a large (7 gallon or 11 gallon size, 1 mil thick) plastic bag. The roughly spherical foam mass was about 40 calibers in diameter. The results are shown in Table 6. Mean PSPL reduction was 17.2 dB, which clearly shows that a larger volume of foams yields a larger PSPL reduction.

A summary of the results of the preliminary foam experiments is shown in Table 7. The foam expansion ratio and the shape and size of the foam mass were not closely measured during these preliminary exploratory experiments. These factors, plus varying wind effects, resulted in considerable data scatter. Since several rounds were fired for each configuration, some general conclusions can nevertheless be drawn. The efficiency of foam for producing significant reductions in muzzle blast noise has been clearly demonstrated. The phenomenological mechanism has not been identified. For foam contained in a plastic bag, the PSPL reduction does not seem to exhibit any consistent significant variation with distance or angle from the line of fire. An increasing amount of foam of constant

* Insignificant compared to the scatter of the data, as well as being less than 3 dB.

Table 7. Summary of Foam Configuration Results

Foam Configuration		Approximate Expansion Ratio	Estimated Foam Ball Diameter (calibers)	Δ PSPL (dB)
A	shaving cream	10	16	-8.2
B		10	20	-11.6
C	aqueous foam	10	25	-10.2
D		20	25	-8.6
E		10	40	-17.2

E.R. yields an increasing PSPL reduction. It appears that an increasing expansion ratio yields a decreasing PSPL reduction (Configurations C and D).

A series of experiments was performed to double check the effect of an empty bag. The bag used was the 1-mil thick 7-gallon size plastic bag used to contain foam configuration "E". Results, shown in Table 8, are consistent with earlier results (Table 1); that is, the empty bag has no significant effect on far field muzzle blast wave PSPL.

A series of experiments was performed, with both the upper and lower gun in bare muzzle condition, to shown the detailed effects of changing atmospheric propagation conditions. These results, shown in Table 9, aid in interpreting results of the other tests, especially in regards to the significance of data scatter. It is also clear that, on the average, far field PSPL is essentially the same for the data and baseline guns.

Another experiment utilized large rubber balloons (100 gm weather balloons) on the muzzle of the gun. Before being placed on the gun muzzle, a balloon was inflated with air just enough to maintain its round shape. The plastic bags

Table 8. Muzzle Blast Attenuation Experiments, Empty Bag

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
1	EB*	--	130.5	122.5	125.8	128.6	135.0	
2	BM**	--	132.5	124.1	127.5	128.4	136.2	
1-2	Δ PSPL	--	-2.0	-1.6	-1.7	+0.2	-1.2	-1.3
3	EB	--	133.2	122.3	126.6	128.4	135.5	
4	BM	--	132.2	121.5	128.0	128.6	136.0	
3-4	Δ PSPL	--	+1.0	+0.8	-1.4	-0.2	-0.5	-0.1
5	EB	--	132.1	123.4	127.2	128.9	135.7	
6	BM	--	130.7	121.4	128.5	128.3	135.5	
5-6	Δ PSPL	--	+1.4	+2.0	-1.3	+0.6	+0.2	+0.6
1-6	Mean Δ PSPL	--	+0.1	+0.4	-1.5	+0.2	-0.5	-0.3

Test date: 8 February 1978. Wind ~ 1 kt variable

* Empty bag (see text)

** Bare Muzzle

Table 9. Muzzle Blast Attenuation Experiments, Bare Muzzle

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
1	BML*	--	131.7	122.6	125.8	129.1	136.2	
2	BMU**	--	131.3	123.8	127.4	129.3	135.1	
1-2	Δ PSPL	--	+0.4	-1.2	-1.6	-0.2	+1.1	-0.3
3	BML	--	134.5	123.9	127.5	130.1	136.6	
4	BMU	--	133.5	122.1	128.4	129.1	135.5	
3-4	Δ PSPL	--	+1.0	+1.8	-0.9	+1.0	+1.1	+0.8
5	BML	--	131.7	124.6	126.4	129.1	135.8	
6	BMU	--	132.4	123.0	128.7	129.2	135.0	
5-6	Δ PSPL	--	-0.7	+1.6	-2.3	-0.1	+0.8	-0.1
7	BML	--	130.8	124.5	127.8	130.8	135.8	
8	BMU	--	133.9	125.0	129.8	129.7	136.3	
7-8	Δ PSPL	--	-3.1	-0.5	-2.0	+1.1	-0.5	-1.0
9	BML	--	131.6	123.1	127.3	128.8	136.1	
10	BMU	--	133.7	122.6	129.5	130.1	135.2	
9-10	Δ PSPL	--	-2.1	+0.5	-2.2	-1.3	+0.9	-0.8
11	BML	--	131.3	123.2	127.7	129.0	135.8	
12	BMU	--	130.6	124.1	128.7	128.8	135.9	
11-12	Δ PSPL	--	+0.7	-0.9	-1.0	+0.2	-0.1	-0.2

Table 9. Muzzle Blast Attenuation Experiments, Bare Muzzle (Cont'd)

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
13	BML	--	130.9	125.5	127.0	129.3	136.1	
14	BMU	--	133.5	125.1	126.8	129.3	135.1	
13-14	Δ PSPL	--	-2.6	+0.4	+0.2	0.0	+1.0	-0.2
15	BML	--	130.9	126.5	126.9	130.5	135.3	
16	BMU	--	132.8	123.9	126.8	129.9	137.6	
15-16	Δ PSPL	--	-1.9	+2.6	+0.1	+0.6	-2.3	-0.2
17	BML	--	130.9	125.2	128.0	129.2	135.3	
18	BMU	--	131.1	122.9	127.3	128.6	136.2	
17-18	Δ PSPL	--	-0.2	+2.3	+0.7	+0.6	-0.9	+0.5
19	BML	--	132.6	126.5	127.4	128.4	135.5	
20	BMU	--	130.6	125.4	127.0	128.3	135.4	
19-20	Δ PSPL	--	+2.0	+1.1	+0.4	+0.1	+0.1	+0.7
1-20	Mean Δ PSPL	--	-0.6	+0.8	-0.9	+0.2	+0.1	-0.1

Test date: 8 February 1978. Wind ~ 3 kt variable

* Bare Muzzle, Lower Gun

** Bare Muzzle, Upper (Baseline) Gun

used in the above experiments invariably ruptured; the rubber balloons were sufficiently strong and flexible to contain the propellant gases without rupturing (except for a small bullet hole). For most of the tests, the balloon remained inflated until the second gun was fired (i.e., about 10 seconds) indicating that the propellant gases were either contained or released slowly. Results are shown in Table 10. Apparently, the shock wave was transmitted across the balloon wall, as the data shows no significant average PSPL reduction. The effect of a nonrupturing balloon filled with aqueous foam was contemplated, however, was not conducted.

CONTAINED FOAM PARAMETER STUDY

A problem with the "foam-in-bag" technique used during the preliminary exploratory experiments is that considerable foam is scattered when the bag ruptures, as shown in Figure 6. This would indicate that probably not all of the foam is utilized for noise reduction. In an attempt to alleviate these drawbacks, a muzzle-mounted metal canister strong enough to withstand the muzzle environment was used to contain the foam. The initial canister configuration was cylindrical in shape, with inside diameter of 12.3 calibers and inside length of 16.7 calibers, mounted with the axis coincident with the gun bore centerline. The forward endcap was removable; the bullet exit hole was 1.4 calibers in diameter. A second canister, identical except that the sidewalls were perforated by 0.4 caliber holes spaced at about 1.5 caliber intervals, was also tested. Both canisters are shown in Figure 7. Test results are listed in Table 11. The scanty data prevents detailed conclusions regarding the exact effect of the various configurations tested; in particular, the open-end canister test results are inconclusive. The results do clearly demonstrate that contained foam yields very significant noise reduction with much smaller quantities of foam than were used in the foam-in-bag tests. It should be noted that these tests do not indicate how much of the noise reduction was due to the canister. For the canister with endcap, after firing there was no residual foam within the canister or scattered around the gun site.

Table 10. Muzzle Blast Attenuation Experiments, Rubber Balloon

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
1	RB*	--	129.4	130.4	124.7	127.3	135.4	
2	BM**	--	133.0	121.9	127.2	129.2	135.9	
1-2	Δ PSPL	--	-3.6	+8.5	-2.5	-1.9	-0.5	0.0
3	RB	--	127.5	126.7	127.8	126.6	134.5	
4	BM	--	134.2	123.8	127.2	129.9	136.2	
3-4	Δ PSPL	--	-6.7	+2.9	+0.6	-3.3	-1.7	-1.6
5	RB	--	128.1	130.2	124.6	126.4	136.4	
6	BM	--	131.1	121.9	128.2	129.8	135.4	
5-6	Δ PSPL	--	-3.0	+8.3	-3.6	-3.4	+1.0	-0.1
7	RB	--	126.4	132.6	127.4	126.7	134.7	
8	BM	--	132.5	124.8	127.2	128.7	134.8	
7-8	Δ PSPL	--	-6.1	+7.8	+0.2	-2.0	-0.1	0.0
9	RB	--	128.0	124.7	124.0	125.4	133.8	
10	BM	--	133.4	121.0	127.0	130.2	135.5	
9-10	Δ PSPL	--	-5.4	+3.7	-3.0	-4.8	-1.7	-2.2

Table 10. Muzzle Blast Attenuation Experiments, Rubber Balloon (Cont'd)

Round Number	Remarks	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =						Mean Δ PSPL (dB)
		45 Right	90 Right	135 Right	135 Left	90 Left	45 Left	
11	RB	--	131.1	127.8	130.5	129.4	133.9	
12	BM	--	134.2	124.0	127.5	128.7	135.4	
11-12	Δ PSPL	--	-3.1	+3.8	+3.0	+0.7	-1.5	+0.6
1-12	Mean Δ PSPL	--	-4.6	+5.8	-0.9	-2.4	-0.8	-0.6

Test date: 8 February 1978. Wind ~ 3 kt variable.

* Rubber Balloon

** Bare Muzzle

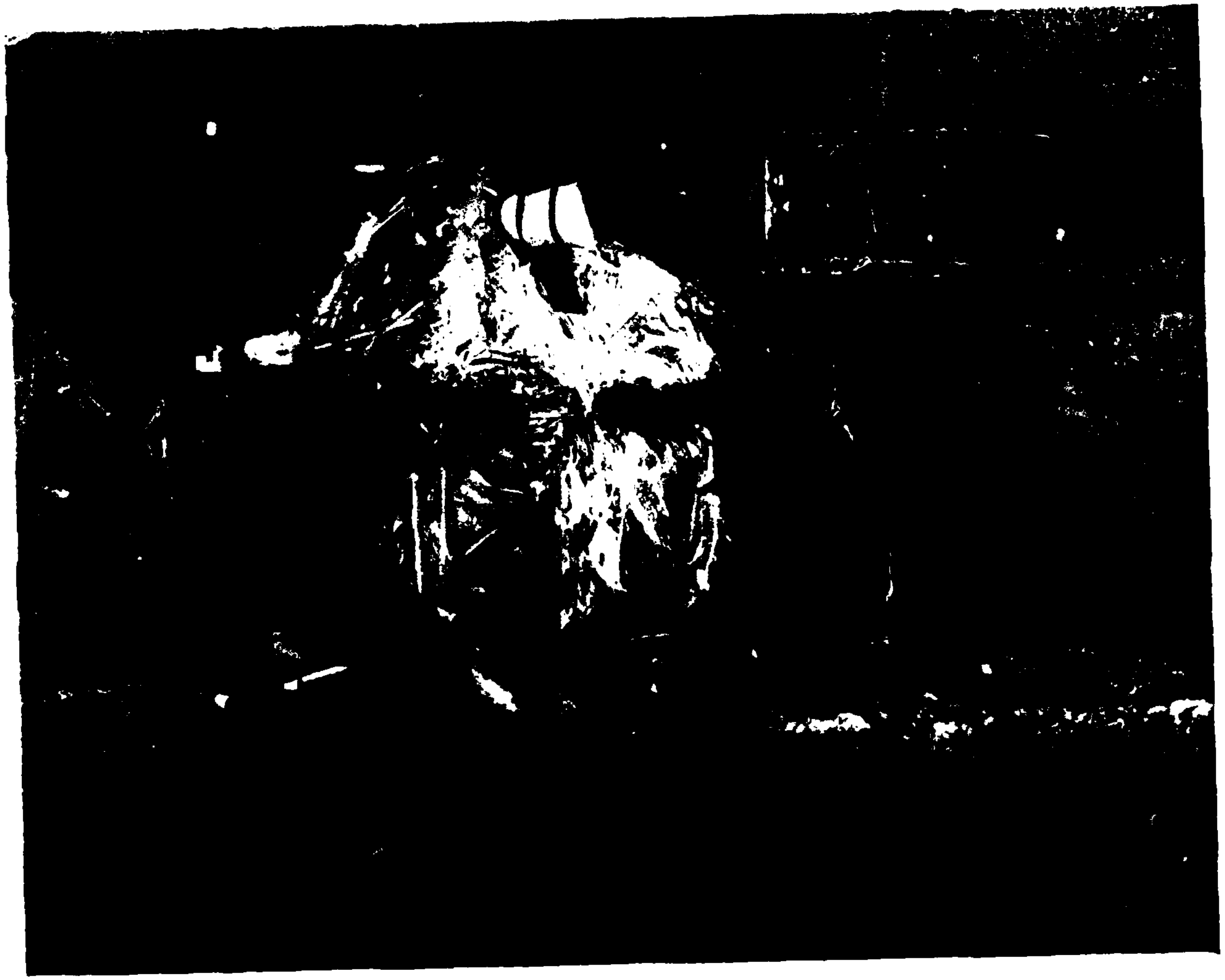

Figure 6. Photo of Gun Site During Foam-in-Bag Experiments

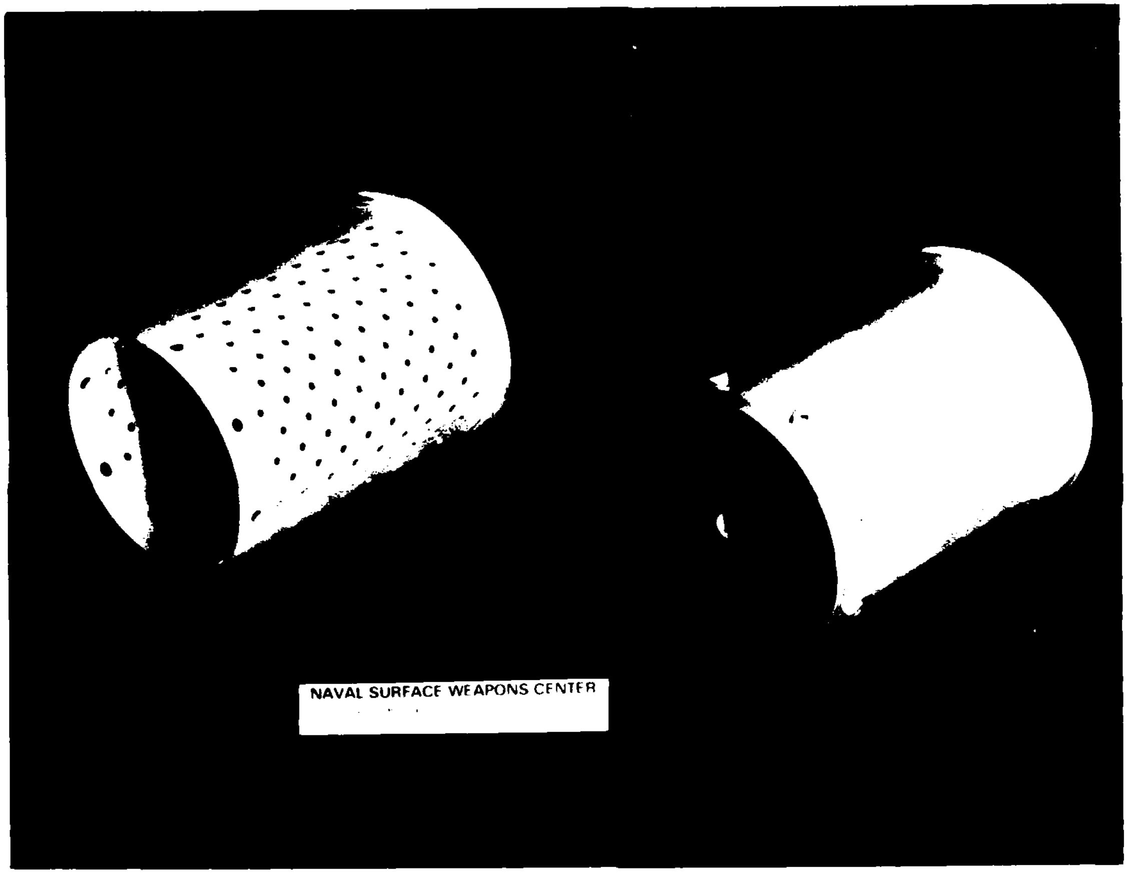

Figure 7. Initial Foam Containment Muzzle Canisters

Table 11. Muzzle Blast Attenuation Experiments: Foam in Metal Canister

Round Number	Remarks	Mean PSPL (dB) @ R = 4000 calibers, angle from direction of fire (degrees) = 45 Right	90 Right	135 Right	Mean Δ PSPL (dB)
1,6,13	Solid wall canister w/endcap, aqueous foam ER ~ 10	124.5	111.7	105.4	
2,7,14	BM*	143.5	134.8	128.4	
1-2,6-7, 13-14	Δ PSPL	-19.0	-23.1	-23.0	-21.7
8	Solid wall canister w/endcap, shaving cream foam	124.1	112.8	105.0	
9	BM	147.2	134.8	128.5	
8-9	Δ PSPL	-23.1	-22.0	-23.5	-22.9
11	Perforated wall canister w/endcap, aqueous foam, ER ~ 10	116.4	116.9	113.2	
12	BM	141.2	133.9	129.0	
11-12	Δ PSPL	-24.8	-17.0	-15.8	-19.2

Table 11. Muzzle Blast Attenuation Experiments:
Foam in Metal Canister (Cont'd)

Round Number	Remarks	Mean PSPL (dB) @ R = 4000 calibers, angle from direction of fire (degrees) = 45 Right	90 Right	135 Right	Mean Δ PSPL (dB)
3	Solid wall canister, open end (no endcap), aqueous foam, ER ~ 10	137.3	130.9	121.7	
4	BM	142.3	134.2	129.7	
3-4	Δ PSPL	-5.0	-3.3	-8.0	-5.4
10	Solid wall canister, open end (no endcap), shaving cream foam	126.6	119.1	111.0	
9,12	BM	144.2	134.4	128.8	
10-9,12	Δ PSPL	-17.6	-15.3	-17.8	-16.9
5	Solid wall canister, open end (no endcap), empty (no foam)	142.6	135.6	127.2	
4,7	BM	143.4	134.6	129.8	
5-4,7	Δ PSPL	-0.8	+1.0	-2.6	-0.8

Test date: 6 April 1978. Wind 5-10 kts variable, from direction of fire.

* Bare Muzzle

The above results motivated a parameter study of muzzle-mounted foam-filled canisters. The dependent variable of primary interest was reduction in far field PSPL. The guns, ammunition, and instrumentation were essentially unchanged throughout the parameter study. Independent variables that were purposely and methodically varied were canister diameter and length. Available parameter values were *inside diameter* D = 2, 4 2/3, 7 1/3, and 10 calibers and inside length L = 5, 10, and 15 calibers by means of the hardware shown in Figure 8. Foam characteristics were desired unchanged, although some random variation undoubtedly occurred and contributed to increased data scatter. The foam used was aqueous foam, E.R. $\tilde{\sim}$ 20, produced by mechanical agitation from a liquid mixture of one part foam concentrate to seven parts water by volume.

The resultant data are listed in tabular form in the Appendix and are summarized in Table 12 and Figures 9 and 10. Several trends can be discerned. Increased diameter or length (and, thus, volume) yields a generally greater PSPL reduction for both foam-filled and empty canisters. It appears that a canister filled with foam yields roughly twice as much PSPL reduction as does the empty canister. Removing the canister endcap (the downrange end of the canister) greatly decreased the resultant PSPL reduction. A particularly interesting result was that the addition of a centrally-located internal baffle yielded a greatly increased PSPL reduction, at least for the D=5 calibers, L=10 calibers configuration tested.

It was noted during the experiments that the visible muzzle signature (muzzle flash and muzzle glow) was significantly reduced by an empty muzzle device. When the muzzle device was filled with foam, the flash was totally eliminated. This was true even at night and even for ammunition that typically produced a large secondary flash from the bare muzzle gun.

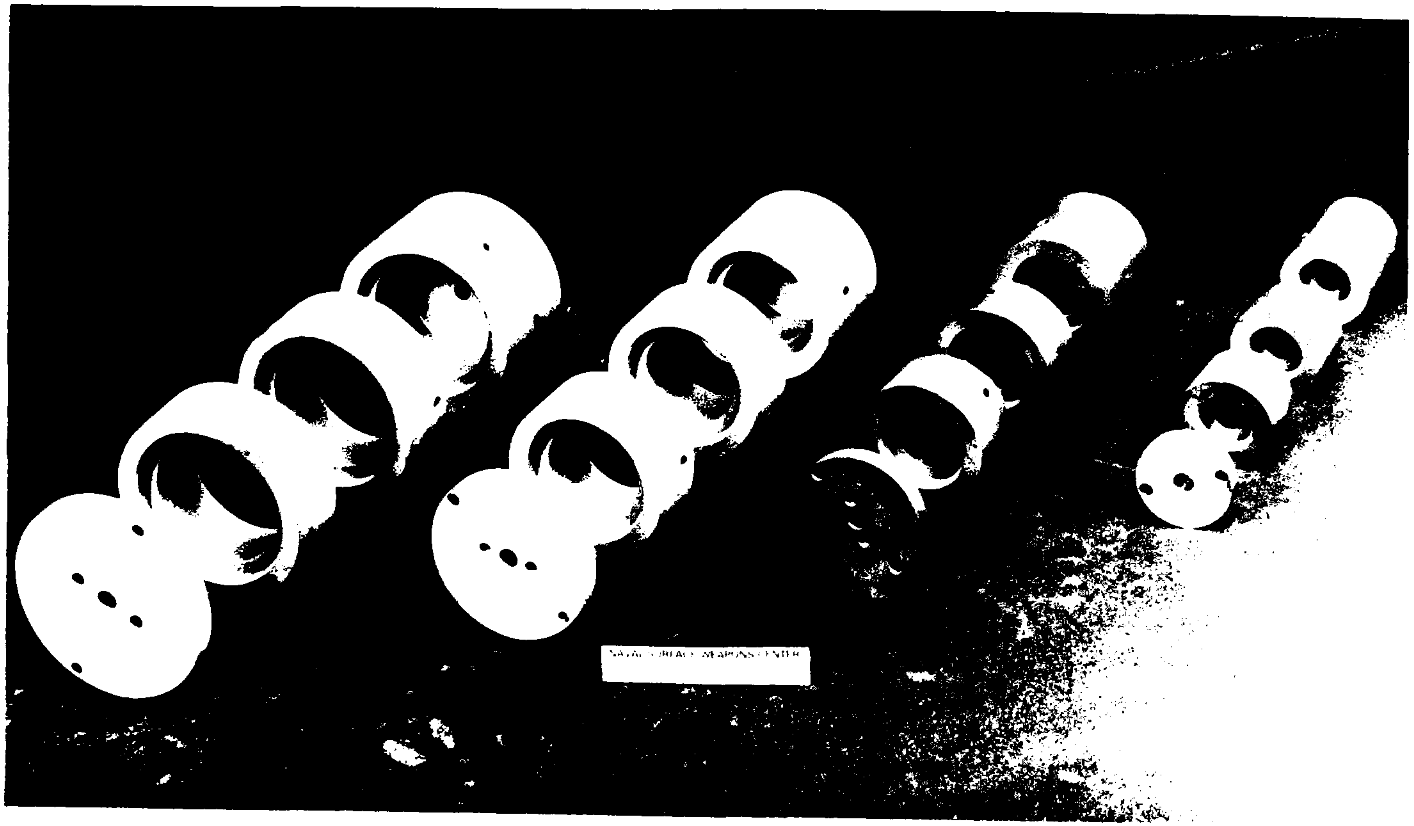

Figure 8. Muzzle Canister Hardware for Contained Foam Parameter Study

Table 12. Contained Foam Parameter Study: Summary of Experimental Results

Round Number	Remarks (End ıp present unless noted) (Nomenclature is D x L)	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
1-8	10 x 5, Foam	-14.4	-13.2	-13.0	-11.2	-13.6	-13.1
9-10	10 x 5, Empty	-4.4	-7.9	-6.8	-6.0	-3.4	-5.7
11-16, 21,26	10 x 10, Foam	-17.5	-16.6	-17.3	-16.5	-11.3	-15.7
17-20	10 x 10, Empty	-6.3	-7.8	-9.6	-6.8	-4.9	-7.1
27-36	10 x 15, Foam	-23.6	-22.8	-19.5	-24.7	-19.3	-22.0
37-44	7 1/3 x 5, Foam	-6.8	-8.7	-8.8	-7.3	-5.0	-7.3
45-54	7 1/3 x 10, Foam	-12.7	-11.1	-12.6	-11.3	-10.2	-11.6
55-62	7 1/3 x 15, Foam	-17.4	-15.4	-17.2	-18.7	-14.2	-16.6
63-64	7 1/3 x 15, Empty	-9.2	-10.9	-12.1	-11.8	-7.8	-10.3
65-74, 79-80	4 2/3 x 5, Foam	-4.3	-8.4	-7.5	-5.0	-3.1	-5.7
75-78	4 2/3 x 5, Empty	-1.5	-3.2	-2.6	-2.4	-1.8	-2.3
81-88	4 2/3 x 10, Foam	-9.2	-10.2	-10.2	-10.4	-6.2	-9.2
89-100	4 2/3 x 15, Foam	-14.6	-12.4	-14.1	-13.0	-12.4	-13.3
101-104	4 2/3 x 15, Empty	-8.0	-9.7	-10.4	-6.9	-8.8	-8.8
105-112	2 x 15, Foam	-3.6	-2.4	-3.1	-3.7	-3.2	-3.2
113-128	10 x 15, Foam, No Endcap	-10.1	-9.1	-9.5	-9.8	-6.4	-9.0

Table 12. Contained Foam Parameter Study: Summary of Experimental Results (Cont'd)

Round Number	Remarks (Endcap present unless noted) (Nomenclature is D x L)	PSPL (dB) @ R = 4000 calibers, Angle from direction of fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
129-132	10 x 10, Foam, No Endcap	-5.8	-4.6	-7.2	-6.0	-2.6	-5.2
133-140	7 1/3 x 15, Foam, No Endcap	-0.1	-1.8	-1.4	-1.2	-0.4	-1.0
141-160	5 x 10, Foam Central Baffle	-15.8	-14.8	-17.4	-14.3	-11.4	-14.7
161-162	5 x 10, Empty, Central Baffle	-6.9	-7.3	-10.1	-5.9	-3.8	-6.8
163-166, 175-178	7 1/3 x 15, Empty	-11.5	-10.9	-12.6	-11.5	-7.5	-10.8
167-174	7 1/3 x 15, Foam	-21.3	-16.5	-20.5	-20.2	-16.1	-18.9
179-186	4 2/3 x 15, Empty	-9.7	-7.9	-6.9	-9.1	-7.4	-8.2
187-194	4 2/3 x 15, Foam	-10.0	-10.9	-10.9	-9.6	-9.2	-10.1
195-202	10 x 10, Empty	-9.6	-10.0	-12.4	-8.6	-6.1	-9.3
203-210	10 x 10, Foam	-14.8	-14.0	-13.8	-12.8	-10.7	-13.2

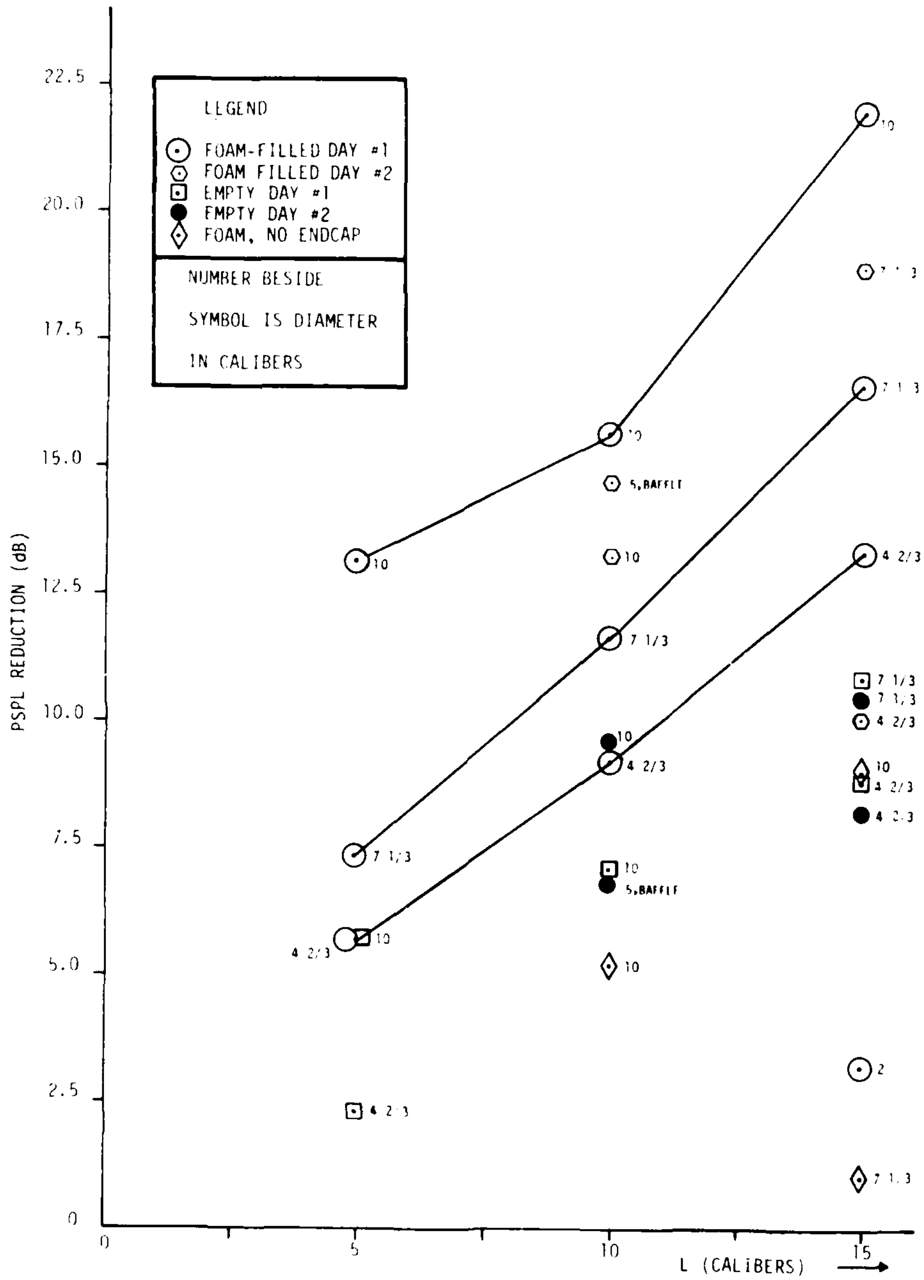

Figure 9. PSPL Reduction vs. Canister Length and Diameter

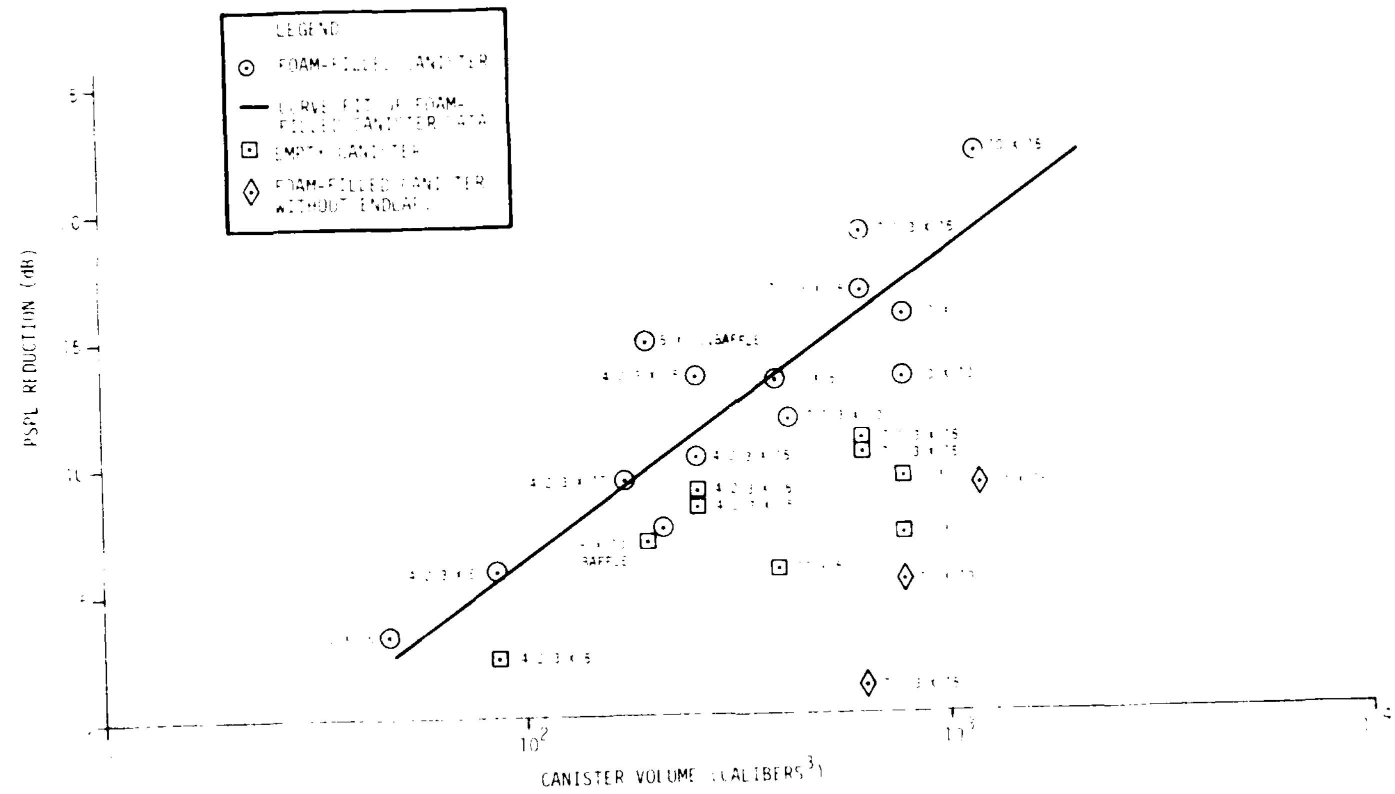

Figure 10. PSPL Reduction vs. Canister Volume

CONCLUSIONS AND RECOMMENDATIONS

It has been conclusively demonstrated that aqueous foam can effect significant (greater than 10 dB) reductions in gun muzzle blast peak sound pressure level. In addition, muzzle flash (including secondary flash) was eliminated completely. The demonstration was carried out using 7.62 mm rifles and aqueous foam with expansion ratio in the range of 10 to 20. It is recommended that further work be carried out using a larger gun and a wider range of foam expansion ratio values.

Containment of the foam in a muzzle-mounted canister appears to offer a feasible and operationally-acceptable method of exploiting the phenomenon, provided that the canister can be made lightweight enough to be used with existing gun systems. Implementation of the technique for a rapid-fire gun would require development of a method for rapidly refilling the canister with foam between shots.

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APPENDIX A

CONTAINED FOAM PARAMETER STUDY:

EXPERIMENTAL DATA

Table A-1. $D = 10$, $L = 5$

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) = 90 Right	135 Right	135 Left	90 Left	45 Left	Mean Δ PSPL (dB)
1	Foam	116.0	113.7	113.5	122.5	122.6	
2	BM	132.5	126.5	129.2	132.0	136.4	
1-2	Δ PSPL	-16.5	-12.8	-15.7	-9.5	-13.8	-13.7
3	Foam	117.9	111.8	116.0	123.0	124.4	
4	BM	131.7	125.9	127.9	133.8	136.9	
3-4	Δ PSPL	-13.8	-14.1	-11.9	-10.8	-12.5	-12.6
5	Foam	117.8	114.9	117.0	120.5	123.9	
6	BM	133.0	126.3	128.5	132.7	137.9	
5-6	Δ PSPL	-15.2	-11.4	-11.5	-12.2	-14.0	-12.9
7	Foam	119.3	111.3	116.0	120.3	124.0	
8	BM	131.2	125.6	128.9	132.7	138.2	
7-8	Δ PSPL	-11.9	-14.3	-12.9	-12.4	-14.2	-13.1
1-8	Mean Δ PSPL, 10 x 5, Foam	-14.4	-13.2	-13.0	-11.2	-13.6	-13.1
9	Empty	127.7	119.9	121.8	127.5	132.4	
10	BM	132.2	127.8	128.6	133.5	135.8	
9-10	Δ PSPL	-4.4	-7.9	-6.8	-6.0	-3.4	-5.7

Test date: 1 May 1978. Wind ~ 5 kts from ~ 135° left.

Table A-2. D = 10, L = 10

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
11	Foam	113.2	109.4	108.8	115.5	124.5	
12	BM	132.3	126.8	127.5	132.2	137.8	
11-12	Δ PSPL	-19.1	-17.4	-18.7	-16.7	-13.3	-17.0
13	Foam	118.2	110.7	110.5	117.8	127.1	
14	BM	133.5	127.5	128.6	133.2	137.0	
13-14	Δ PSPL	-15.3	-16.8	-18.1	-15.4	-9.9	-15.1
15	Foam	--	112.4	113.2	118.5	126.2	
16	BM	134.4	127.4	129.4	133.4	136.6	
15-16	Δ PSPL	--	-15.0	-16.2	-14.9	-10.4	-14.1
17	Empty	127.3	119.2	117.4	127.3	130.3	
18	BM	133.6	128.2	128.8	132.5	137.2	
17-18	Δ PSPL	-6.3	-9.0	-11.4	-5.2	-6.9	-7.8
19	Empty	--	120.3	120.0	124.6	132.2	
20	BM	135.4	126.9	127.7	133.0	135.0	
19-20		--	-6.6	-7.7	-8.4	-2.8	-6.4
21	Foam	118.3	110.5	110.8	116.4	126.3	
22	BM	133.6	128.4	127.2	133.6	136.8	
21-22	Δ PSPL	-15.3	-17.9	-16.4	-17.2	-10.5	-15.5

Table A-2. D = 10, L = 10 (Cont'd)

Round Number	Remarks (End cap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
23	Foam	117.6	112.6	111.8	117.4	125.4	
24	BM	134.7	126.6	127.6	133.1	136.9	
23-24	Δ PSPL	-17.1	-14.0	-15.8	-15.7	-11.5	-14.8
25	Foam	112.7	109.0	109.9	114.0	124.3	
26	BM	133.6	127.6	128.6	132.8	136.2	
25-26	Δ PSPL	-20.9	-18.6	-18.7	-18.8	-11.9	-17.8
11-16, 21-26	Mean Δ PSPL, 10 x 10, Foam	-17.5	-16.6	-17.3	-16.5	-11.3	-15.7
17-20	Mean Δ PSPL, 10 x 10, Empty	-6.3	-7.8	-9.6	-6.8	-4.9	-7.1

Test date: 1 May 1978 and 2 May 1978. Wind ~ 5 kts from ~ 135° left.

Table A-3. D = 10, L = 15

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) = 90 Right	135 Right	135 Left	90 Left	45 Left	Mean Δ PSPL (dB)
27	Foam	109.5	103.2	107.4	105.7	115.8	
28	BM	133.1	128.6	127.8	133.9	137.1	
27-28	Δ PSPL	-23.6	-25.4	-20.4	-28.2	-21.3	-23.8
29	Foam	109.8	105.3	105.5	106.8	118.4	
30	BM	132.8	127.7	127.7	134.2	137.1	
29-30	Δ PSPL	-23.0	-22.4	-22.2	-27.4	-18.7	-22.8
31	Foam	108.0	105.2	105.5	111.3	115.0	
32	BM	133.1	126.6	127.6	133.5	135.7	
31-32	Δ PSPL	-25.1	-21.4	-22.1	-22.2	-20.7	-22.3
33	Foam	109.2	102.7	108.4	110.0	116.8	
34	BM	133.5	126.7	126.3	133.1	136.3	
33-34	Δ PSPL	-24.3	-24.0	-17.9	-23.1	-19.5	-21.8
35	Foam	112.3	106.8	111.6	110.3	119.7	
36	BM	134.3	127.8	126.6	133.1	136.1	
35-36	Δ PSPL	-22.0	-21.0	-15.0	-22.8	-16.3	-19.4
27-36	Mean Δ PSPL, 10 x 15, Foam	-23.6	-22.8	-19.5	-24.7	-19.3	-22.0

Test date: 2 May 1978. Wind ~ 2 kts from ~ 135° left.

Table A-4. D = 7 1/3, L = 5

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
37	Foam	126.2	117.8	118.4	125.5	131.1	
38	BM	132.9	125.6	127.3	132.6	134.8	
37-38	Δ PSPL	-6.7	-7.8	-8.9	-7.1	-3.7	-6.8
39	Foam	125.0	117.5	119.9	125.5	129.7	
40	BM	133.6	127.0	127.6	132.4	136.8	
39-40	Δ PSPL	-8.6	-9.5	-7.7	-6.9	-7.1	-8.0
41	Foam	126.2	119.9	118.8	125.0	131.5	
42	BM	132.2	127.4	126.8	132.7	136.6	
41-42	Δ PSPL	-6.0	-7.5	-8.0	-7.7	-5.1	-6.9
43	Foam	127.3	118.2	117.7	125.4	131.7	
44	BM	133.4	128.2	128.1	132.9	135.6	
43-44	Δ PSPL	-6.1	-10.0	-10.4	-7.5	-3.9	-7.6
37-44	Mean Δ PSPL, 7 1/3 x 5, Foam	-6.8	-8.7	-8.8	-7.3	-5.0	-7.3

Test date: 2 May 1978. Winds ~ calm.

Table A-5. D = 7 1/3, L = 10

Round Number	Remarks (Endcap present for all rounds) (BM = Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
45	Foam	120.8	119.0	113.7	121.6	128.3	
46	BM	132.3	127.2	127.5	132.0	136.6	
45-46	Δ PSPL	-11.5	-8.2	-13.8	-10.4	-8.3	-10.4
47	Foam	118.1	117.5	114.7	122.4	125.4	
48	BM	133.1	128.0	129.7	133.1	137.9	
47-48	Δ PSPL	-15.0	-10.5	-15.0	-10.7	-12.5	-12.8
49	Foam	121.8	115.5	115.8	120.5	125.6	
50	BM	133.1	127.0	129.9	132.9	137.8	
49-50	Δ PSPL	-11.3	-11.5	-14.1	-12.4	-12.2	-12.3
51	Foam	122.3	117.0	117.8	121.8	126.9	
52	BM	134.4	127.0	127.7	132.4	137.6	
51-52	Δ PSPL	-12.[illegible]	-10.0	-9.9	-10.6	-10.7	-10.7
53	Foam	120.1	113.5	118.0	120.6	128.7	
54	BM	133.4	128.7	128.2	133.0	136.1	
53-54	Δ PSPL	-13.3	-15.2	-10.2	-12.4	-7.4	-11.7
45-54	Mean Δ PSPL, 7 1/3 x 10, Foam	-12.7	-11.1	-12.6	-11.3	-10.2	-11.6

Test date: 2 May 1978. Wind 5-10 kts variable from ~ 135° left.

Table A-6. D = 7 1/3, L = 15

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
55	Foam	119.0	114.3	113.2	113.7	123.6	
56	BM	132.7	127.4	128.5	133.2	136.5	
55-56	Δ PSPL	-13.7	-13.1	-15.3	-19.5	-12.9	-14.9
57	Foam	107.7	110.8	106.5	107.2	115.4	
58	BM	132.5	127.2	128.1	133.2	135.7	
57-58	Δ PSPL	-24.8	-16.4	-21.6	-26.0	-20.3	-21.8
59	Foam	118.1	112.6	111.9	118.8	124.2	
60	BM	133.3	127.3	127.9	131.8	136.4	
59-60	Δ PSPL	-15.2	-14.7	-16.0	-13.0	-12.2	-14.3
61	Foam	117.9	111.0	112.3	116.7	124.3	
62	BM	133.8	128.3	127.8	132.8	135.7	
61-62	Δ PSPL	-15.9	-17.3	-15.5	-16.1	-11.4	-15.2
55-62	Mean Δ PSPL, 7 1/3 x 15, Foam	-17.4	-15.4	-17.2	-18.7	-14.2	-16.6
63	Empty	123.9	116.1	116.4	122.3	129.2	
64	BM	133.1	127.0	128.5	134.1	137.0	
63-64	Δ PSPL, 7 1/3 x 15, Empty	-9.2	-10.9	-12.1	-11.8	-7.8	-10.3

Test date: 2 May 1978. Wind 3-10 kts variable from ~ 135° left.

Table A-7. D = 4 2/3, L = 5

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
65	Foam	130.0	121.1	122.5	130.2	133.8	
66	BM	132.7	128.0	127.0	133.6	136.2	
65-66	Δ PSPL	-2.7	-6.9	-4.5	-3.4	-2.4	-4.0
67	Foam	128.8	120.3	120.6	128.1	133.6	
68	BM	133.6	127.3	128.0	133.1	136.4	
67-68	Δ PSPL	-4.8	-7.0	-7.4	-5.0	-2.8	-5.4
69	Foam	127.2	116.2	118.2	125.5	131.2	
70	BM	132.9	127.9	128.3	132.4	136.6	
69-70	Δ PSPL	-5.7	-11.7	-10.1	-6.9	-5.4	-8.0
71	Foam	128.1	119.8	119.4	127.8	134.0	
72	BM	132.6	128.2	128.1	132.7	136.4	
71-72	Δ PSPL	-4.5	-8.4	-8.7	-4.9	-2.4	-5.8
73	Foam	127.8	118.3	119.4	129.3	131.4	
74	BM	131.7	127.3	127.8	133.7	133.9	
73-74	Δ PSPL	-3.9	-9.0	-8.4	-4.4	-2.5	-5.6
75	Empty	132.2	125.7	126.2	131.6	135.5	
76	BM	134.1	128.5	128.9	134.0	137.0	
75-76	Δ PSPL	-1.9	-2.8	-2.7	-2.4	-1.5	-2.3
77	Empty	132.9	124.9	126.5	132.0	134.7	
78	BM	134.0	128.6	128.9	134.5	136.8	

Table A-7. D = 4 2/3, L = 5 (Cont'd)

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
77-78	Δ PSPL	-1.1	-3.7	-2.4	-2.5	-2.1	-2.3
79	Foam	130.0	121.6	123.0	128.9	133.7	
80	BM	134.0	129.2	128.8	134.4	137.0	
79-80	Δ PSPL	-4.0	-7.6	-5.8	-5.5	-3.3	-5.2
65-74, 79-80	Mean Δ PSPL, 4 2/3 x 5, Foam	-4.3	-8.4	-7.5	-5.0	-3.1	-5.7
75-78	Mean Δ PSPL, 4 2/3 x 5, Empty	-1.5	-3.2	-2.6	-2.4	-1.8	-2.3

Test date: 2 and 3 May 1978. Wind 0-5 kts variable.

Table A-8. D = 4 2/3, L = 10

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
81	Foam	124.3	118.4	118.2	123.3	131.2	
82	BM	133.6	129..	128.8	133.6	137.1	
81-82	Δ PSPL	-9.3	-11.3	-10.6	-10.3	-5.9	-9.5
83	Foam	124.0	117.3	119.1	123.4	131.4	
84	BM	133.1	127.6	130.0	132.1	136.8	
83-84	Δ PSPL	-9.1	-10.3	-10.9	-8.7	-5.4	-8.9
85	Foam	124.4	116.9	118.7	123.2	130.2	
86	BM	133.3	128.4	128.8	132.9	137.0	
85-86	Δ PSPL	-8.9	-11.5	-10.1	-9.7	-6.8	-9.4
87	Foam	124.6	120.4	120.7	122.0	131.1	
88	BM	134.0	128.0	130.1	134.8	138.0	
87-88	Δ PSPL	-9.4	-7.6	-9.4	-12.8	-6.9	-9.2
81-88	Mean Δ PSPL, 4 2/3 x 10, Foam	-9.2	-10.2	-10.2	-10.4	-6.2	-9.2

Test date: 3 May 1978. Wind 0-5 kts variable, from ~ direction of fire.

Table A-9. D = 4 2/3, L = 15

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) = 90 Right	135 Right	135 Left	90 Left	45 Left	Mean Δ PSPL (dB)
89	Foam	116.6	115.3	114.8	120.4	124.7	
90	BM	134.7	127.1	129.8	133.2	138.5	
89-90	Δ PSPL	-18.1	-11.8	-15.0	-12.8	-13.8	-14.3
91	Foam	118.8	113.9	114.2	119.0	123.5	
92	BM	134.0	129.1	129.7	134.1	137.2	
91-92	Δ PSPL	-15.2	-15.2	-15.5	-15.1	-13.7	-15.0
93	Foam	121.2	117.3	114.5	119.4	127.1	
94	BM	135.5	129.2	129.8	134.1	138.1	
93-94	Δ PSPL	-14.3	-11.9	-15.3	-14.7	-11.0	-13.4
95	Foam	119.8	116.3	114.8	123.3	124.2	
96	BM	133.7	128.1	128.7	133.5	135.9	
95-96	Δ PSPL	-13.9	-11.8	-13.9	-10.2	-11.7	-12.3
97	Foam	121.1	117.6	118.2	122.4	125.6	
98	BM	135.4	128.8	128.9	134.0	138.2	
97-98	Δ PSPL	-14.3	-11.2	-10.7	-11.6	-12.6	-12.1
99	Foam	121.6	116.5	113.5	121.4	125.9	
100	BM	133.4	128.6	127.4	134.8	137.2	
99-100	Δ PSPL	-11.8	-12.1	-13.9	-13.4	-11.3	-12.5
101	Empty	127.9	118.5	119.5	127.0	129.3	

Table A-9. D = 4 2/3, L = 15 (Cont'd)

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
102	BM	133.1	130.1	128.8	133.5	138.1	
101-102	Δ PSPL	-5.2	-11.6	-9.3	-6.6	-8.8	-8.3
103	Empty	125.0	121.0	120.1	127.1	128.1	
104	BM	135.9	128.7	131.5	134.3	137.1	
103-104	Δ PSPL	-10.9	-7.8	-11.4	-7.2	-8.9	-9.2
89-100	Mean Δ PSPL, 4 2/3 x 15, *Foam*	-14.6	-12.4	-14.1	-13.0	-12.4	-13.3
101-104	Mean Δ PSPL, 4 2/3 x 15, Empty	-8.0	-9.7	-10.4	-6.9	-8.8	-8.8

Test date: 3 May 1978. Wind 0-10 kts variable, from ~ direction of fire.

Table A-10. D = 2, L = 15

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	*PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =*					*Mean* Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
105	Foam	131.5	124.6	125.2	131.2	134.2	
106	BM	134.7	128.8	127.9	133.7	137.9	
105-106	Δ PSPL	-3.2	-4.2	-2.7	-2.5	-3.7	-3.3
107	Foam	130.9	125.2	125.6	129.2	135.0	
108	BM	133.8	127.6	128.7	133.5	137.7	
107-108	Δ PSPL	-2.9	-2.4	-3.1	-4.3	-2.7	-3.1
109	Foam	130.1	125.4	126.2	129.3	133.1	
110	BM	135.2	126.7	129.3	132.7	137.2	
109-110	Δ PSPL	-5.1	-1.3	-3.1	-3.4	-4.1	-3.4
111	Foam	130.4	126.2	125.2	129.5	134.5	
112	BM	133.7	127.9	128.6	134.2	136.6	
111-112	Δ PSPL	-3.3	-1.7	-3.4	-4.7	-2.1	-3.0
105-112	Mean Δ PSPL, 2 x 15, Foam	-3.6	-2.4	-3.1	-3.7	-3.2	-3.2

Test date: 3 May 1978. Wind 2-10 kts variable from ~ direction of fire.

Table A-11. D = 10, L = 15, Without Endcap

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
113	Foam	126.4	118.2	120.9	127.1	132.9	
114	BM	134.1	125.2	129.1	133.2	137.6	
113-114	Δ PSPL	-7.7	-7.0	-8.2	-6.1	-4.7	-6.8
115	Foam	121.2	115.7	118.2	123.3	133.1	
116	BM	133.3	125.4	129.7	133.3	138.4	
115-116	Δ PSPL	-12.1	-9.7	-11.5	-10.0	-5.3	-9.7
117	Foam	124.2	117.0	121.3	124.0	131.3	
118	BM	133.5	126.6	129.8	134.3	136.0	
117-118	Δ PSPL	-9.3	-9.6	-8.5	-10.3	-4.7	-8.5
119	Foam	122.4	116.7	118.7	120.2	128.7	
120	BM	135.0	129.0	130.5	134.5	136.7	
119-120	Δ PSPL	-12.6	-12.3	-11.8	-14.3	-8.0	-11.8
121	Foam	124.0	118.3	121.4	125.5	131.2	
122	BM	137.7	125.9	128.8	133.8	137.3	
121-122	Δ PSPL	-13.7	-7.6	-7.4	-8.3	-6.1	-8.6
123	Foam	126.9	120.4	120.6	124.8	132.7	
124	BM	133.1	126.9	129.5	133.6	137.4	
123-124	Δ PSPL	-6.2	-6.5	-8.9	-8.8	-4.7	-7.0

Table A-11. D = 10, L = 15, Without Endcap (Cont'd)

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) = 90 Right	135 Right	135 Left	90 Left	45 Left	Mean Δ PSPL (dB)
125	Foam	123.7	118.0	120.6	122.5	129.2	
126	BM	133.8	127.7	130.0	133.6	140.1	
125-126	Δ PSPL	-10.1	-9.7	-9.4	-11.1	-10.9	-10.3
127	Foam	124.2	118.0	119.3	123.8	131.6	
128	BM	133.2	128.4	129.4	133.1	138.2	
127-128	Δ PSPL	-9.0	-10.4	-10.1	-9.3	-6.6	-9.1
113-128	Mean Δ PSPL, 10 x 15, Foam, No Endcap	-10.1	-9.1	-9.5	-9.8	-6.4	-9.0

Test date: 5 May 1978. Wind 5-10 kts variable from ~ 45° left.

Table A-12. D = 10, L = 10, Without Endcap

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
129	Foam	128.2	119.7	121.2	127.5	133.6	
130	BM	132.9	126.8	128.5	133.6	136.8	
129-130	Δ PSPL	-4.7	-7.1	-7.3	-6.1	-3.2	-5.7
131	Foam	127.1	125.0	121.5	126.6	136.5	
132	BM	133.9	127.0	128.7	132.5	138.6	
131-132	Δ PSPL	-6.8	-2.0	-7.2	-5.9	-2.1	-4.8
129-132	Mean Δ PSPL, 10 x 10, Foam, No Endcap	-5.8	-4.6	-7.2	-6.0	-2.6	-5.2

Test date: 5 May 1978. Wind 5-10 kts variable from ~ 45° left.

Table A-13. D = 7 1/3, L = 15, Without Endcap

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
133	Foam	134.3	127.0	128.1	132.9	139.2	
134	BM	134.9	127.9	129.3	135.3	138.6	
133-134	Δ PSPL	-0.6	-0.9	-1.2	-2.4	+0.6	-0.9
135	Foam	133.6	125.1	128.8	133.0	137.7	
136	BM	134.2	127.8	129.3	133.2	138.7	
135-136	Δ PSPL	-0.6	-2.7	-0.5	-0.2	-1.0	-1.0
137	Foam	133.4	126.4	127.0	132.4	137.4	
138	BM	135.5	127.2	129.5	132.4	138.6	
137-138	Δ PSPL	-2.1	-0.8	-2.5	0.0	-1.2	-1.3
139	Foam	135.3	124.4	127.1	131.5	136.2	
140	BM	132.4	127.0	128.4	133.8	136.2	
139-140	Δ PSPL	+2.9	-2.6	-1.3	-2.3	0.0	-0.7
133-140	Mean Δ PSPL, 7 1/3 x 15, Foam, No Endcap	-0.1	-1.8	-1.4	-1.2	-0.4	-1.0

Test date: 5 May 1978. Wind 5-10 kts variable from ~ 45° left.

Table A-14. D = 5, L = 10, With Central Internal Baffle

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
141	Foam	118.8	112.6	111.3	120.0	125.4	
142	BM	134.5	128.0	130.5	132.1	138.0	
141-142	Δ PSPL	-15.7	-15.4	-19.2	-12.1	-12.6	-15.0
143	Foam	118.6	114.6	115.2	121.3	126.4	
144	BM	133.5	127.1	128.9	133.0	137.7	
143-144	Δ PSPL	-14.9	-12.5	-13.7	-11.7	-11.3	-12.8
145	Foam	120.9	113.1	112.1	119.9	127.0	
146	BM	133.5	126.6	129.6	134.4	136.9	
145-146	Δ PSPL	-12.6	-13.5	-17.5	-14.5	-9.9	-13.6
147	Foam	120.5	112.9	112.3	119.7	126.7	
148	BM	134.1	128.8	127.5	133.8	136.9	
147-148	Δ PSPL	-13.6	-15.9	-15.2	-14.1	-10.2	-13.8
149	Foam	116.5	112.3	110.3	117.7	126.9	
150	BM	134.7	126.9	129.6	133.2	140.4	
149-150	Δ PSPL	-18.2	-14.6	-19.3	-15.5	-13.5	-16.2
151	Foam	117.6	111.9	110.7	119.0	126.4	
152	BM	135.2	127.6	128.8	134.1	136.2	
151-152	Δ PSPL	-17.6	-15.7	-18.1	-15.1	-9.8	-15.3

Table A-14. D = 5, L = 10, With Central Internal Baffle (Cont'd)

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
153	Foam	115.2	112.9	111.7	115.4	124.2	
154	BM	135.8	127.2	128.2	133.3	135.8	
153-154	Δ PSPL	-20.6	-14.3	-16.5	-17.9	-11.6	-16.2
155	Foam	119.2	110.8	110.8	117.6	126.0	
156	BM	133.4	128.3	130.2	132.9	138.2	
155-156	Δ PSPL	-14.2	-17.5	-19.4	-15.3	-12.2	-15.7
157	Foam	120.0	112.9	110.6	120.9	126.8	
158	BM	134.2	126.8	128.6	133.3	138.4	
157-158	Δ PSPL	-14.2	-13.9	-18.0	-12.4	-11.6	-14.0
159	Foam	120.4	114.4	111.9	119.0	126.4	
160	BM	136.7	128.9	128.6	133.7	137.2	
159-160	Δ PSPL	-16.3	-14.5	-16.7	-14.7	-10.8	-14.6
141-160	Mean Δ PSPL, 5 x 10, Central Baffle, Foam	-15.8	-14.8	-17.4	-14.3	-11.4	-14.7
161	Empty	127.6	121.1	120.4	128.5	136.0	
162	BM	134.5	128.4	130.5	134.4	139.8	
161-162	Δ PSPL, Empty	-6.9	-7.3	-10.1	-5.9	-3.8	-6.8

Test date: 5 May 1978. Wind 5-10 kts variable from ~ 45° left.

Table A-15. D = 7 1/3, L = 15

Round Number	Remarks (Endcap present for all rounds) (BM = Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) = 90 Right	135 Right	135 Left	90 Left	45 Left	Mean Δ PSPL (dB)
163	Empty	122.1	115.3	119.0	122.4	130.7	
164	BM	135.3	127.8	129.2	131.6	138.3	
163-164	Δ PSPL	-13.2	-12.5	-10.2	-9.2	-10.3	-11.1
165	Empty	123.5	118.7	116.5	121.8	132.9	
166	BM	135.1	127.4	128.8	136.4	138.0	
165-166	Δ PSPL	-11.6	-8.7	-12.3	-14.6	-5.1	-10.5
167	Foam	117.1	111.8	113.2	117.3	126.6	
168	BM	135.6	129.6	130.5	134.1	138.9	
167-168	Δ PSPL	-18.5	-17.8	-17.3	-16.8	-12.3	-16.5
169	Foam	113.8	113.1	104.7	112.4	120.0	
170	BM	135.3	128.1	127.4	135.7	137.8	
169-170	Δ PSPL	-21.5	-15.0	-22.7	-23.3	-17.8	-20.1
171	Foam	113.6	113.5	108.5	113.2	123.0	
172	BM	136.3	128.4	129.8	134.5	139.0	
171-172	Δ PSPL	-22.7	-14.9	-21.3	-21.3	-16.0	-19.2
173	Foam	111.6	111.8	108.4	113.8	119.1	
174	BM	134.2	130.0	129.0	133.0	137.5	
173-174	Δ PSPL	-22.6	-18.2	-20.6	-19.2	-18.4	-19.8

Table A-15. D = 7 1/3, L = 15 (Cont'd)

Round Number	Remarks (Endcap present for all rounds) (BM = Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
175	Empty	125.3	116.5	115.6	123.5	130.0	
176	BM	135.8	128.9	129.9	133.8	136.9	
175-176	Δ PSPL	-10.5	-12.4	-14.3	-10.3	-6.9	-10.9
177	Empty	124.0	119.7	115.3	121.8	129.5	
178	BM	134.5	129.6	128.8	133.6	137.2	
177-178	Δ PSPL	-10.5	-9.9	-13.5	-11.8	-7.7	-10.7
163-166, 175-178	Mean Δ PSPL, 7 1/3 x 15, Empty	-11.5	-10.9	-12.6	-11.5	-7.5	-10.8
167-174	Mean Δ PSPL, 7 1/3 x 15, Foam	-21.3	-16.5	-20.5	-20.2	-16.1	-18.9

Test date: 21-22 May 1978. Winds 0-5 kts variable.

Table A-16. D = 4 2/3, L = 15

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
179	Empty	125.1	120.5	121.6	123.8	132.4	
180	BM	134.3	129.1	129.5	133.2	137.9	
179-180	Δ PSPL	-9.2	-8.6	-7.9	-9.4	-5.5	-8.1
181	Empty	125.0	120.6	122.8	124.5	129.8	
182	BM	135.4	128.1	129.8	133.4	138.1	
181-182	Δ PSPL	-10.4	-7.5	-7.0	-8.9	-8.3	-8.4
183	Empty	125.2	121.1	122.2	125.1	129.6	
184	BM	135.4	128.1	129.0	133.0	138.1	
183-184	Δ PSPL	-10.2	-7.0	-6.8	-7.9	-8.5	-8.1
185	Empty	124.6	120.6	123.5	123.9	129.7	
186	BM	133.4	129.2	129.4	134.2	137.1	
185-186	Δ PSPL	-8.8	-8.6	-5.9	-10.3	-7.4	-8.2
187	Foam	124.1	118.9	119.5	124.1	128.8	
188	BM	133.9	128.3	127.2	133.5	137.7	
187-188	Δ PSPL	-9.8	-9.4	-7.7	-9.4	-8.9	-9.0
189	Foam	121.1	114.7	113.2	122.5	126.1	
190	BM	133.6	128.9	128.3	132.6	136.9	
189-190	Δ PSPL	-12.5	-14.2	-15.1	-10.1	-10.8	-12.5

Table A-16. D = 4 2/3, L = 15 (Cont'd)

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) = 90 Right	135 Right	135 Left	90 Left	45 Left	Mean Δ PSPL (dB)
191	Foam	125.3	118.5	118.4	123.9	127.4	
192	BM	134.4	128.6	129.7	133.4	136.6	
191-192	Δ PSPL	-9.1	-10.1	-11.3	-9.5	-9.2	-9.8
193	Foam	125.6	119.6	118.3	125.2	128.7	
194	BM	134.4	129.3	127.8	134.6	136.7	
193-194	Δ PSPL	-8.8	-9.7	-9.5	-9.4	-8.0	-9.1
179-186	Mean Δ PSPL, 4 2/3 x 15, Empty	-9.7	-7.9	-6.9	-9.1	-7.4	-8.2
187-194	Mean Δ PSPL, 4 2/3 x 15, Foam	-10.0	-10.9	-10.9	-9.6	-9.2	-10.1

Test date: 21-22 May 1978. Wind 2-5 kts variable.

Table A-17. D = 10, L = 10

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
195	Empty	131.3	121.7	120.5	129.2	131.8	
196	BM	134.4	128.4	129.9	134.4	137.7	
195-196	Δ PSPL	-3.1	-6.7	-9.4	-5.2	-5.9	-6.1
197	Empty	122.6	118.6	117.5	122.3	130.0	
198	BM	134.0	129.5	128.3	134.6	137.6	
197-198	Δ PSPL	-11.4	-10.9	-10.8	-12.3	-[illegible].6	-10.6
199	Empty	123.2	118.0	114.9	123.7	131.2	
200	BM	136.1	128.2	128.9	133.3	136.8	
199-200	Δ PSPL	-12.9	-10.2	-14.0	-9.6	-5.6	-10.5
201	Empty	124.2	116.6	115.3	122.7	131.3	
202	BM	135.2	128.9	130.5	130.0	136.7	
201-202	Δ PSPL	-11.0	-12.3	-15.2	-7.3	-5.4	-10.2
203	Foam	122.0	115.3	115.5	121.4	126.0	
204	BM	135.1	129.1	130.4	133.3	135.9	
203-204	Δ PSPL	-13.1	-13.8	-14.9	-11.9	-9.9	-12.7
205	Foam	120.4	114.0	115.7	122.2	126.5	
206	BM	134.9	128.9	128.7	133.1	137.3	
205-206	Δ PSPL	-14.5	-14.9	-13.0	-10.9	-10.8	-12.8

Table A-17. $D = 10$, $L = 10$ (Cont'd)

Round Number	Remarks (Endcap present for all rounds) (BM → Bare Muzzle)	PSPL (dB) @ R = 4000 calibers, Angle from Direction of Fire (degrees) =					Mean Δ PSPL (dB)
		90 Right	135 Right	135 Left	90 Left	45 Left	
207	Foam	119.1	113.5	114.8	121.7	125.8	
208	BM	135.5	128.2	129.2	134.9	137.7	
207-208	Δ PSPL	-16.4	-14.7	-14.4	-13.2	-11.9	-14.1
209	Foam	118.8	115.8	116.0	119.0	127.6	
210	BM	133.9	128.3	128.9	134.2	137.6	
209-210	Δ PSPL	-15.1	-12.5	-12.9	-15.2	-10.0	-13.1
195-202	Mean Δ PSPL, 10 x 10, Empty	-9.6	-10.0	-12.4	-8.6	-6.1	-9.3
203-210	Mean Δ PSPL, 10 x 10, Foam	-14.8	-14.0	-13.8	-12.8	-10.7	-13.2

Test date: 21-22 May 1978. Wind 0-5 kts variable.

Table A-18. Effect of Foam-Filled Canister on Projectile Exit Velocity

Round Number	Projectile Velocity (ft/sec)	Remarks
211	2387	
212	2420	
213	2390	
214	2409	D x L (calibers)
215	2383	=10 x 15, Foam
216	2413	
217	2417	
218	2417	
219	2400	
220	2403	
211-220	2404	Mean
211-220	13.5	Std Deviation
221	2406	
222	2406	
223	2426	
224	2368	
225	2423	
226	2410	
227	2413	
228	2407	Bare Muzzle
229	2436	
230	2426	
231	2437	
232	2407	
233	2418	
234	2411	
235	2409	
236	2428	
237	2426	
238	2408	
221-238	2415	Mean
221-238	15.6	Std Deviation

Test date: 25-26 May 1978

Table A-19. Muzzle Flash Experiment

Round Number	Remarks (D x L in calibers)	Muzzle Flash Description
239	10 x 15, Foam	None
240	BM	Large
241	10 x 15, Foam	None
242	BM	Large
243	10 x 15, Foam	None
244	BM	Large
245	10 x 15, Foam	None
246	BM	Large
247	10 x 15, Foam	None
248	BM	Large
249	10 x 15, Foam	None
250	BM	Large
251	10 x 15, Empty	Small
252	BM	Large
253	10 x 15, Empty	Small
254	10 x 15, Empty	Small
255	BM	Large
256	10 x 15, Empty	Small
257	BM	Large

Test date: 25-26 May 1978

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